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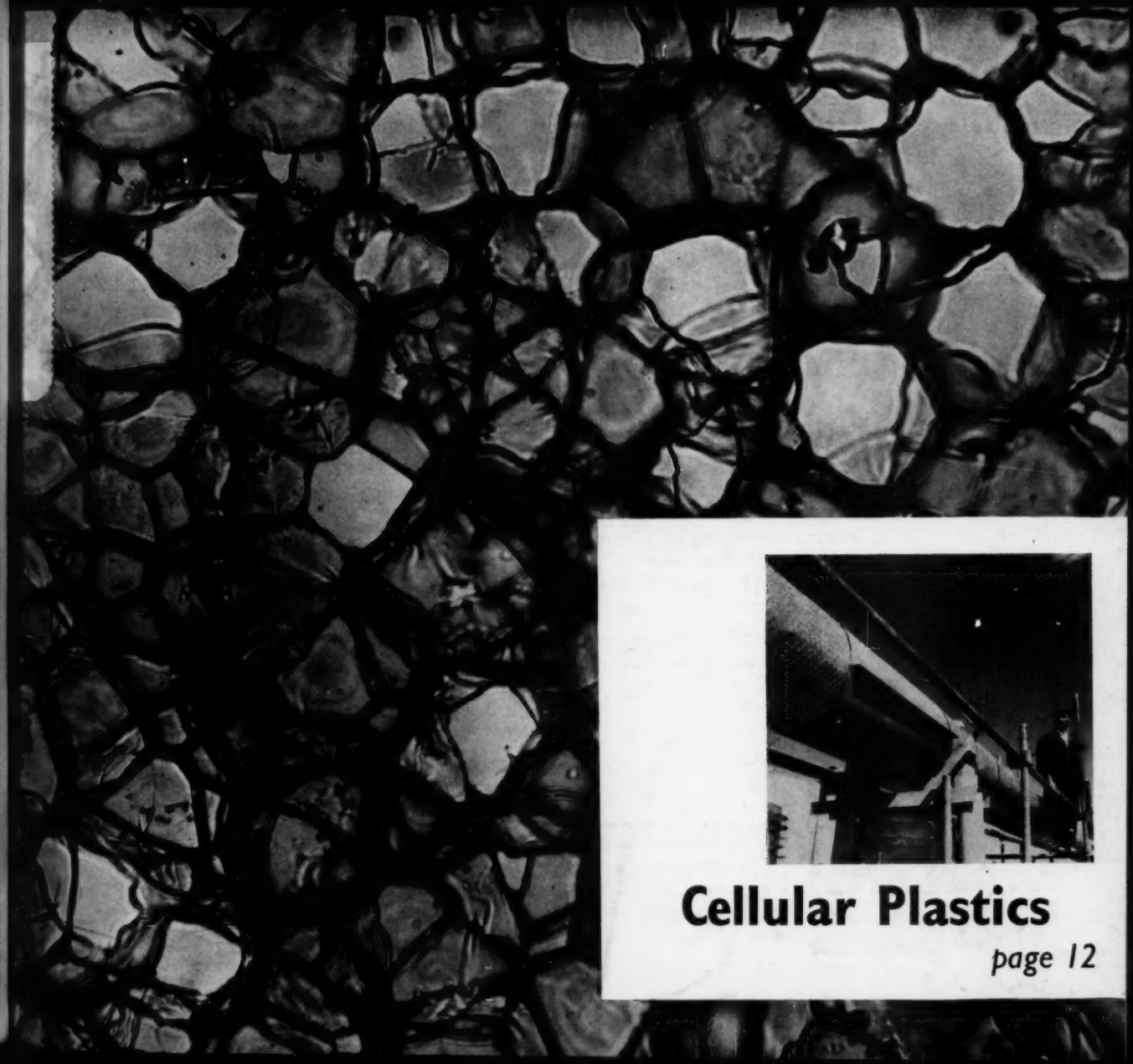

Cellular Plastics

page 12

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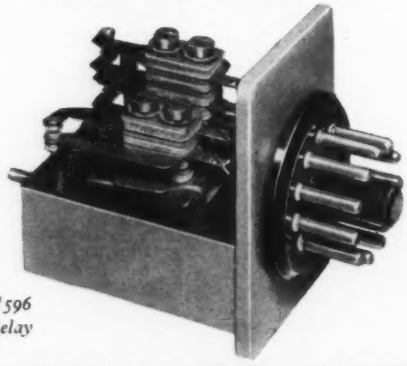

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★ *The Magazine for Engineering Designers*

A HEYWOOD PUBLICATION

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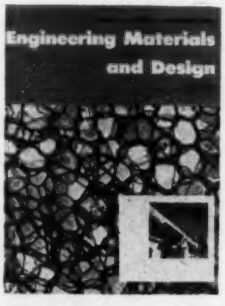

COVER: Illustrating the cellular structure of Polyzote expanded polystyrene, with inset a view of an aluminium pipe (for liquid methane) insulated with Onazote expanded ebonite (Expanded Rubber Co. Ltd.).

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PLASTIQUES CELLULAIRES

par L. N. Phillips page 12

Après avoir examiné brièvement les méthodes d'expansion (mousses), l'auteur étudie la procédure de sélection et les propriétés physiques des diverses matières plastiques cellulaires. Dans sa conclusion, il décrit 10 formes de matières plastiques ayant une importance commerciale.

APPLICATION DES ISOTOPES DANS L'INDUSTRIE

page 35

Au cours d'une conférence sur l'emploi des radio-isotopes dans les Sciences Physiques et dans l'Industrie, organisée dernièrement à Copenhague, les délégués ont examiné de nouvelles techniques intéressant les ingénieurs. L'auteur de l'article étudie les communications sur les applications des éléments traceurs. Ces communiqués ont porté sur " La recherche sur la lubrification et l'usure ", " L'ecoulement des liquides et des gaz " et les " Accumulateurs ".

RENSEIGNEMENTS POUR INGENIEURS

par F. Machon page 28

L'auteur examine les services d'information technique dont disposent les ingénieurs dans le Royaume-Uni et recommande certaines méthodes permettant d'obtenir les renseignements que l'on désire dans de nombreux domaines.

MOTEURS DIESEL JUSQU'A 300 CV : 3ÈME PARTIE

page 31

Troisième et dernière partie d'une étude complète présentant les caractéristiques et spécifications, sous forme de tableaux, des moteurs Diesel fabriqués dans le Royaume-Uni.

Kurzreferate

ZELLSTOFFE

von L. N. Phillips Seite 12

Nach einer kurzen Besprechung der verschiedenen Schäumungsmethoden bespricht der Verfasser die Wahl und die physikalischen Eigenschaften verschiedener Zellstoffe. Im letzten Abschnitt werden schliesslich zehn kommerziell wichtige Formen dieses Materials beschrieben.

ISOTOPE IM MASCHINENBAU

Seite 35

Anlässlich einer Konferenz über den Einsatz von Radioisotopen in der Physik und Industrie in Kopenhagen wurde neue Techniken besprochen. Der Artikel bespricht die Vorträge über Indikatoren, und insbesondere über „Forschungen im Gebiet der Schmierung und des Verschleisses", „Der Fluss von Flüssigkeiten und Gasen" und „Akkumulatorenbatterien".

DATEN FÜR INGENIEURE

von F. Machon Seite 28

Der Autor zählt die Ingenieuren in Grossbritannien zur Verfügung stehenden technischen Informationsdienste auf und bespricht die Lösung von Informationsproblemen verschiedener Art.

DIESELMOTORE BIS ZU 300 BREMS-P.S. — TEIL III

Seite 31

Der Schluss einer umfassenden Übersicht mit Konstruktionsdaten und Tabellen über Dieselmotore britischer Erzeugung.

Резюме

КЛЕТЧАТАЯ ПЛАСТМАССА

Л. Н. Филлипс стр. 12

Перечислив вкратце методы экспансии вспенивания, автор статьи обсуждает процесс отбора и физические качества различных сортов клетчатой пластмассы. В заключительной части статьи описываются десять коммерчески важных сортов этого материала.

ПРИМЕНЕНИЕ ИЗОТОПОВ В ТЕХНОЛОГИИ

стр. 35

Новые технические процессы представляющие большой интерес для инженеров, обсуждались недавно в Копенгагене на конференции по вопросу применения радио-изотопов в науке и промышленности. В этой статье обсуждаются представленные конференции доклады о трассирующих применениях, в частности на следующие темы : — «Исследование в области смазки и износа», «Поток жидкостей и газов», и «Аккумуляторные батареи».

ИНФОРМАЦИЯ ДЛЯ ИНЖЕНЕРОВ

Ф. Мэчон стр. 28

Статья перечисляет службы технической информации для инженеров в Соединенном Королевстве и рекомендует методы подхода к различным информационным проблемам.

ДИЗЕЛЬНЫЕ ДВИГАТЕЛИ ДО 300 т.л.с. — ЧАСТЬ 3ая стр. 31

Заключительная часть всесоб' емлющего обзора, включающего виды конструкции и таблицы данных о дизельных двигателях производимых в Соединенном Королевстве.

MATERIALS IN THE NEWS

Monthly Digest of Materials and Design News from Home and Abroad

Next Stage for High-speed Aircraft

THE MINISTER OF AVIATION, Mr. Thorneycroft, recently told the House of Commons that the Government had selected the British Aircraft Corp. to undertake further work on a limited design study contract for a possible supersonic airliner project, and that a contract for the work was being negotiated.

Sir George Edwards, executive director, aircraft, of the British Aircraft Corp., and managing director of Vickers Armstrongs (Aircraft), favoured the development of a 1,500 m.p.h. (just over Mach 2) aircraft rather than a 2,000 m.p.h. (Mach 3) aircraft. He recently said: "The British just about know how to do the slower one and, I think, have every intention of doing it. The Americans could undoubtedly find out how to do it. Neither of us knows how to do the 2,000 m.p.h. one, and do not be misled by anyone who says he does." In any case, he had grave doubts whether airlines would be able to absorb anything more than the 1,500 m.p.h. aeroplane; their previous biggest jump had been from 350 to 500 m.p.h.

On the matter of how soon the supersonic transport should be ready, Sir George said that he doubted very much if even the 1,500 m.p.h. airliner would be ready to carry passengers "before the 1970s." He was also quite certain that the airlines would not be able to afford it before then.

One of the biggest problems which the British Aircraft Corp. will have to investigate is the question of noise. It is almost a foregone conclusion that any further increase in airport noise will not be tolerated. This problem has already been given no small amount of attention by British aircraft and aero-engine designers, and it seems certain that revised take-off techniques—perhaps vertical take-off—with very elaborate silencing arrangements will have to be developed before the supersonic airliners can go into service. In order to reduce take-off noise to levels at least no greater than present subsonic airliners, it may be necessary to develop a new kind of engine based on the turbofan or bypass principles, which would provide adequate thrust with an acceptable noise level on the ground and which, by adoption of a moderate degree of re-heat at altitude, would give the thrust required to accelerate to, and maintain, supersonic cruising speeds.

Tyres for Ships' Fenders

OVER A PROLONGED PERIOD, many proposals and designs for ships' fenders have been raised; several of these projects proved quite workable, but the majority were of an improvised nature and were not entirely satisfactory under working conditions. With the designing of large oil tankers, the problem became one of urgency to enable vessels to discharge the whole or part of their cargoes into smaller tankers in the open sea. This operation was essential so as to avoid the necessity of such ships with exceptional draught entering port at all. In addition, it would enable them to discharge oil at ports where they would be precluded from calling due to insufficient water. The same remarks apply to passenger-cargo vessels.

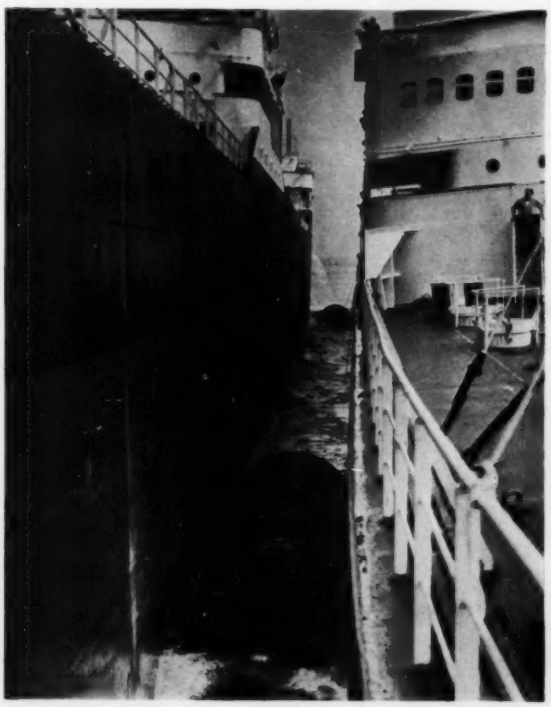
From an investigation into this particular problem carried out by Wing Commander Bennet Burleigh, M.B.E., of Marine Craft Constructors Ltd., there has been developed a provisionally patented fender which, by the tests carried out, appears to be the solution. The design is relatively simple. It involves the use of five giant tubeless tyres, 10 ft. in diameter, each revolving separately on its own bearings, mounted on a specially constructed steel cylinder having rotating swivel and eyes at each end.

Once launched into the sea, the fender would only be lifted out for service, and it was therefore essential that there should be the minimum of corrosion between the wheel rims and the steel cylinders. Furthermore, the design and subsequent materials used in the manufacture of these rims would have to withstand the possible force of deflection of one or more tyres caused by the impact of a 40,000-ton ship, and one of 30,000 tons drawing alongside at a speed of up to 5 knots, together with the continuous impact caused by rolling and pitching in a rough sea or heavy swell.

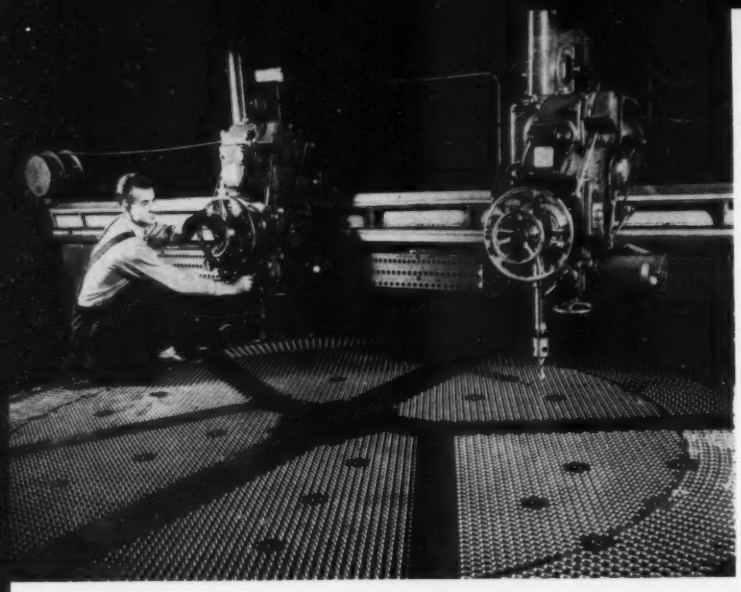
These rims were originally designed for production as aluminium alloy sand-castings, but were ultimately produced as hand forgings from cast billets in Hiduminium 35 at the Forging Division of High Duty Alloys Ltd. The change in the process was purely for metallurgical reasons. In a component of this size produced as a forging, the properties, due to the structure of the metal, will be uniform throughout, whereas if produced as a casting, there could be slight variations.

A further interesting application of aluminium in the construction of the fenders was for the tyre valves. Normally, brass is used, but to prevent any action between the Hiduminium rim and the valve, A. Schrader's & Son made special valves in Hiduminium 35 with hard anodised threads to give added strength.

The giant tyres, five of which are used in each fender and which are inflated to 50 p.s.i., were supplied by the Firestone Tyre and Rubber Co., Ltd.



Tubeless rubber tyres with aluminium rims being used as ships' fenders.



PICTURE NEWS

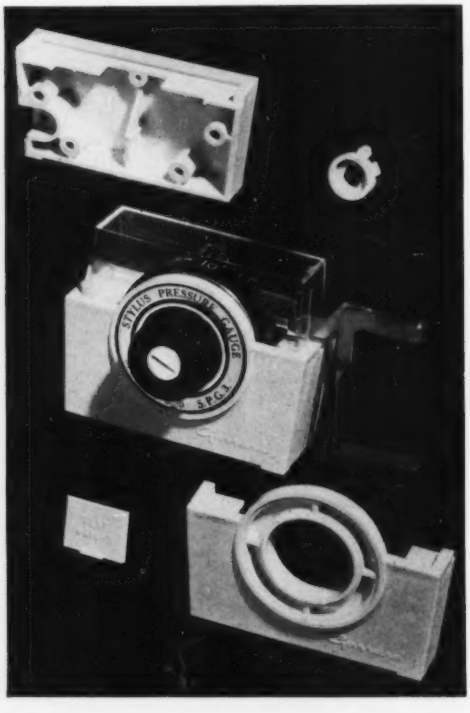
IN THE WORLD OF MATERIALS & DESIGN

PHOTOGRAPHY IN ENGINEERING

This photograph, showing a condenser tube plate being drilled in the A.E.I. Heat Exchange Works, is one of twelve taken by W. Ralston Ltd. and selected for inclusion in the "Best Industrial Photographs of the Year" display at the Photographic and Television Exhibition.

PLASTICS FOR PRECISION GAUGE

To ensure correct stylus pressure for playing gramophone records, the precision gauge shown below is being manufactured by Garrard Engineering & Manufacturing Co. Ltd. The components for the case are moulded in Styron polystyrene, made by British Resin Products.

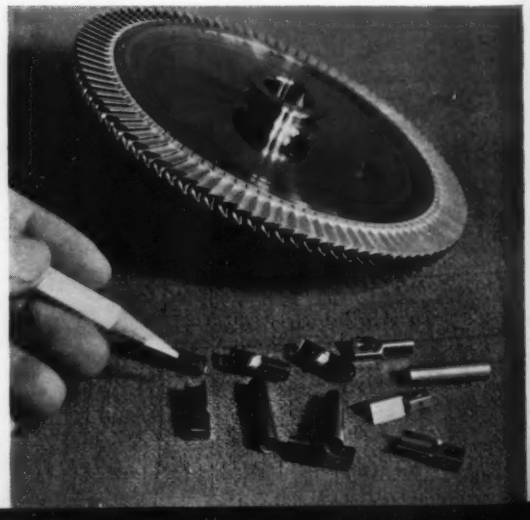


IMPROVED TV CAMERA

This Marconi closed-circuit television camera is fitted with a new and improved two-lens turret, which can accommodate any pair of standard lenses having focal lengths between 10 and 150 mm. The lens change mechanism is motor driven and remotely operated.

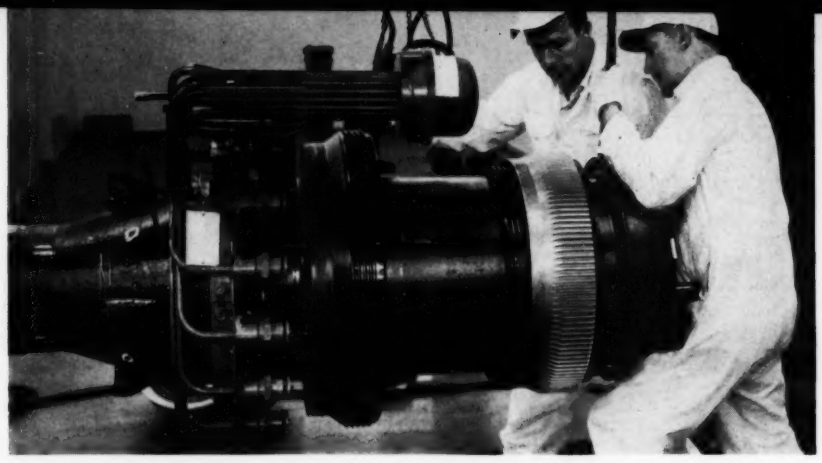
LIGHTWEIGHT TURBINE WHEEL

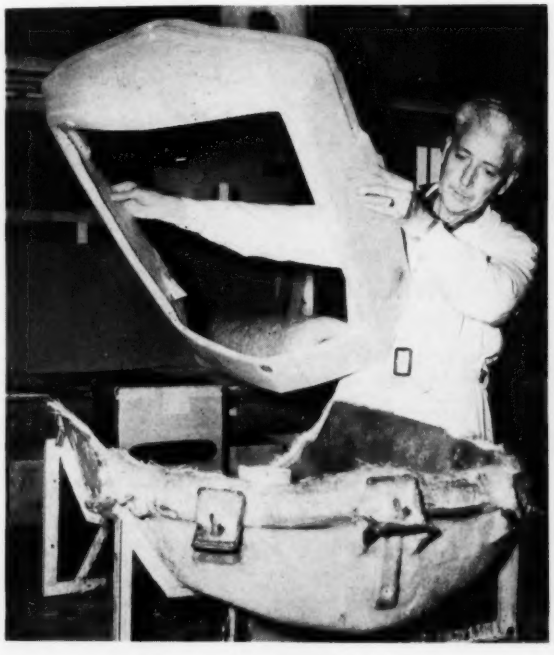
Sheet-metal turbine buckets have cut the weight and cost of this turbine wheel by more than 50 per cent. The General Electric Co., New York, claim that this is the first practical application of sheet-metal buckets, which are made from a new high-temperature nickel-base alloy.



ULTRA-CLEAN ASSEMBLY

The right-hand picture shows the fitting of a loading ring to a control rod standpipe manufactured for the Hunterston Nuclear Power Station by Stewarts & Lloyds. Scrupulous cleanliness is necessary, because certain elements present in dust particles could damp down the nuclear reaction and also make the gas stream radioactive.



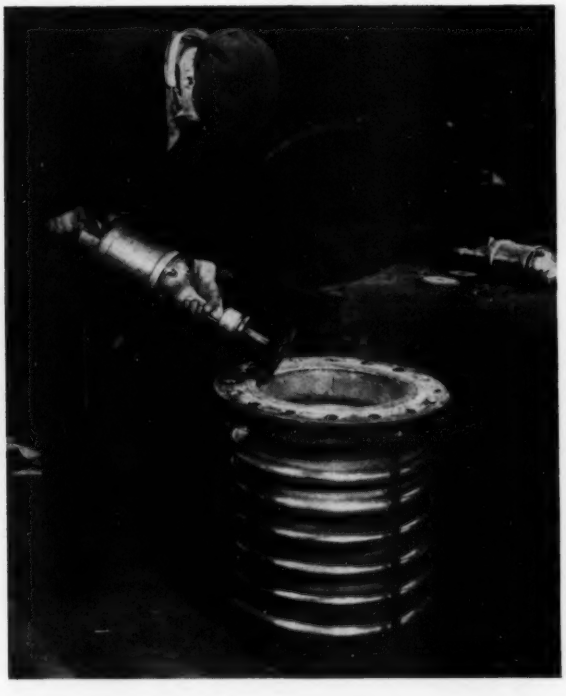


STAINLESS STEEL FOR CLEANING BELLOWS

A Consolidated Pneumatic type-5180 Hicycle grinder fitted with a stainless steel wire brush for cleaning purposes on a non-equalising bellows unit.

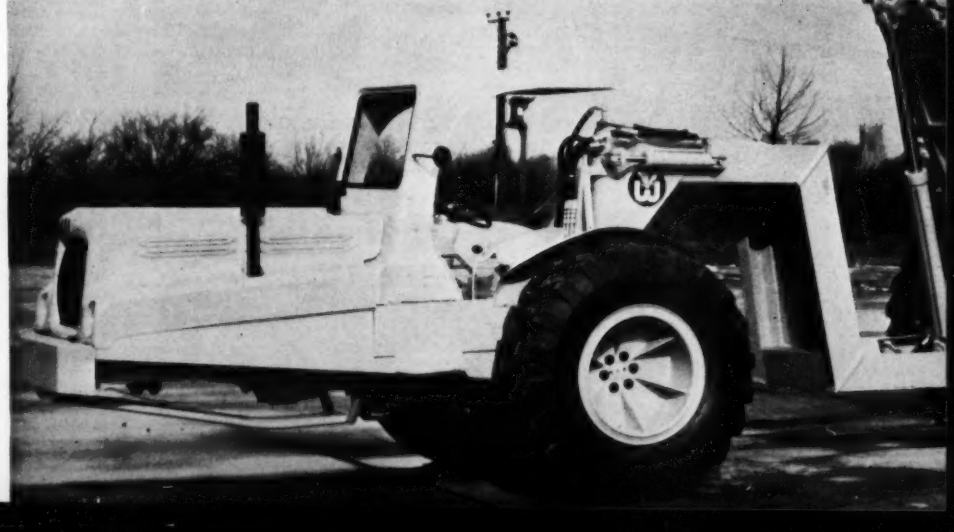
GLASS-FIBRE RADIATOR COWLS

Plastics have replaced metal in this radiator cowl made by Vanden Plas (British Motor Corp.). It is said to show several advantages, but at the same time to be indistinguishable from the metal cowl after painting.

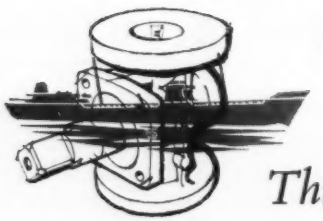


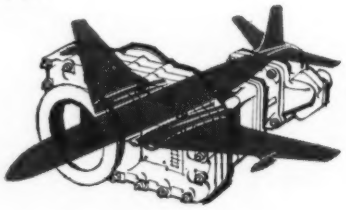
EARTHMOVING EQUIPMENT USES PLASTICS

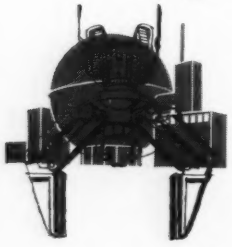
Whitlock Brothers Ltd. have recently introduced a new range of heavy earthmoving equipment, which makes extensive use of reinforced polyester resin for the construction of cabs. This construction allows great flexibility and speed in design, and modifications can be rapidly realised.

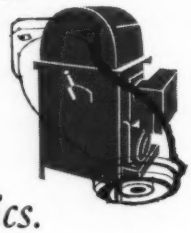


Kanigen *a hard, non-porous corrosion-resistant plate, gives complete uniform coverage even to the most intricately shaped parts. Thickness can be controlled to fine limits. Being chemically deposited Kanigen can be applied to practically all metals in commercial use. It can also be applied to non-conductors such as plastics and ceramics.*









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TSW/701

"Packaged" Switching Station

A NEW OUTDOOR "PACKAGED" SWITCHING STATION is being produced by English Electric. Called the Weatherbeater, this completely self-contained 33-kV unit occupies little more space than a conventional indoor installation, and much less than a normal outdoor station. Associated civil engineering costs are low, as the unit needs only a simple concrete raft foundation. No building is necessary. The exterior weatherproof housing is of aluminium, which needs no painting or periodic maintenance.

The station is built from standard units, each 16 ft. 9 in. high x 12 ft. 3 in. deep. A 1200-amp. unit is 6 ft. 6 in. wide, and a 1600-2000 amp. 7 ft. 3 in. wide. Each unit houses either an English Electric OKM4 or OKM5 single-tank oil circuit-breaker for current ratings up to 1200 and 2000 amp. respectively. It is available in single busbar form for short-circuit ratings of 750 and 1000 MVA.

Isolation is by means of hand-operated isolators on both sides of the circuit breaker. Built-in cable and, where required, busbar earthing equipment are included, as well as hand-operated safety shutters. All the usual interlocks associated with metal-clad gear are provided. The isolators, earthing equipment and shutters are all operated from a single control point mounted on the side of each unit. Operation is simple and quick, and the mechanical interlocking ensures that the correct sequence is always followed.

A model of the Weatherbeater will be shown at the A.S.E.E. Exhibition, Earls Court, March 21-25, 1961.

Aluminium Sheathed Cable for Railway Electrification

A FURTHER PHASE in the British Transport Commission's Modernisation Plan was completed on November 6 1960, when the electrified lines in the Eastern Region, from London (Liverpool Street) to Shenfield and Southend, began to operate at high voltage a.c. for the first time.

As part of the overall plan for the conversion of this line, the B.I.C.C. Group have manufactured and installed 1800 yards route length of double circuit 0.85-sq. in. 25-kV/earth concentric oil-filled cable of the corrugated seamless aluminium (c.s.a.) sheathed type. The high resistance of aluminium to vibration fatigue makes aluminium sheathed cables particularly suitable for railway work, while the reduced weight and high flexibility of c.s.a. type cable is of great advantage for all forms of installation. The smaller sheath wall thickness which the corrugated technique permits results in reduced cable costs. Protection against corrosion of the aluminium sheath is provided by means of an extruded p.v.c. outer serving, the integrity of which is tested electrically after manufacture and following installation.

The major portion of the cable route follows the railway track, where the cables run above ground on concrete posts. The mechanical strength and reduced weight of the cable permits the support to be spaced at 15-ft. intervals, thereby further reducing installation costs.

Fabrication of Rocket Thrust Chambers

A UNIQUE CONCEPT in the fabrication of rocket thrust chambers, that of ribbon-wrapped, U-shaped channels, is being used by Solar Aircraft Co. in San Diego on a project for the National Aeronautics and Space Administration. Unlike the tube-type regeneratively-cooled thrust chambers that Solar has been furnace-brazing for major missile and space vehicle programmes, this ribbon-wrap construction, conceived and designed by N.S.A., applies an entirely new approach to design, materials and fabrication.

The brazed thrust chambers will be used for testing new high-energy liquid propellants that require strong rocket thrust chambers to withstand very high heat flux. The sheet metal channels provide an easy yet precise method of controlling the coolant passage area throughout the chamber, which has been designed to conduct heat away efficiently from the thin metal by varying the fuel coolant velocity to meet local heat conditions. This new process offers an extremely lightweight, yet strong chamber, and provides greater design flexibility with lower costs than other types of construction.

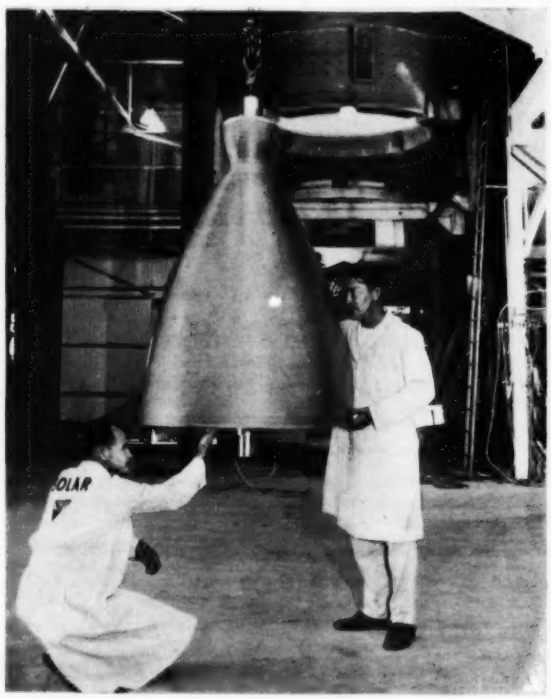
In fabricating the chambers, 360 straight strips of 0.008-in. AM350 stainless steel sheet are blanked out, then formed and sized into a U channel in one operation on a one-piece die representing the angular segment of the engine. Following this operation, 180 of these channels are assembled from the top of the chamber head to a stainless steel mandrel that has been cast and machine contoured to the desired chamber configuration. Then, 180 more channels are joined "piggy-back" at the neck of the hour glass-shaped chamber, and generally fed into a skirt with the other 180.

The channels are racked, with the open side facing out, by the use of notched clamping devices, and then welded together with approximately 100,000 spot welds. The welds are easily and quickly applied in a specific pattern to ensure close fit-up and hold dimensional and configuration requirements.

The assembly is annealed in a hydrogen atmosphere in order to hot size the channel to the exact shape of the mandrel. The chamber is then put on a lathe which Solar have especially adapted to this programme, where the channels are sized and electro-ground to specified heights along the entire chamber length.

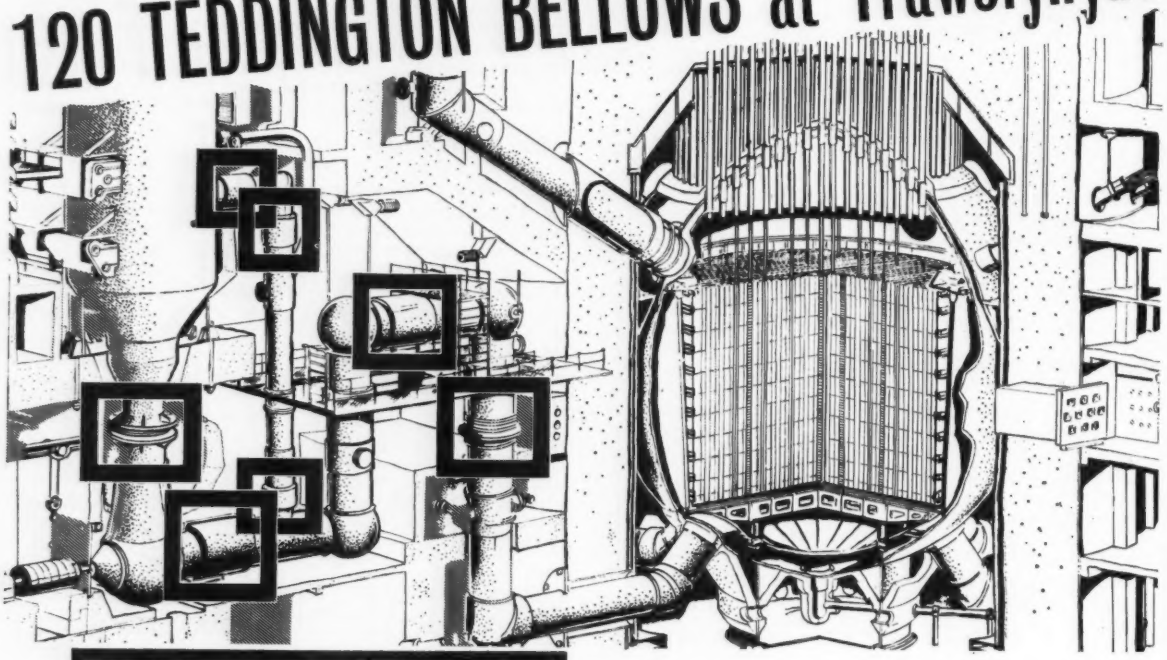
Following the grinding, while still on the lathe, the chamber is wrapped tightly with approximately 2650 ft. of 0.008-in. AM350 (same as the channels) stainless steel ribbon. This ribbon, along with a copper brazing ribbon, is fed automatically around the chamber from a feeding spool geared to the revolutions of the lathe Following the wrapping, additional copper braze filler is sprayed on to the chamber to provide external sealing of interlocked ribbons. The chamber is then ready for brazing, which integrates the wrapping and channels into tube-like fuel passages.

Multiple brazing techniques developed by Solar are used in the next step. Attachments such as the fuel manifold, reinforcing rings and injector flange are fitted to the chamber, and the second braze operation begins. This takes place at approximately 1025 deg. C., a copper-tin brazing alloy being used. The chamber is then machined to mate the injector and engine mount, and the assembly is heat treated (this is necessary to achieve the desired metallurgical properties of precipitation hardened AM350). This operation is carried out in a split cycle of −73 deg. C. for 3 hr., followed by 3 hr. at 540 deg. C.



This unique thrust chamber, built by Solar Aircraft Co. for N.A.S.A., features fuel passages made of 120 U-shaped channels wrapped with stainless steel ribbon and then brazed into a single unit.

120 TEDDINGTON BELLOWS at Trawsfynydd



By courtesy of 'NUCLEAR POWER'

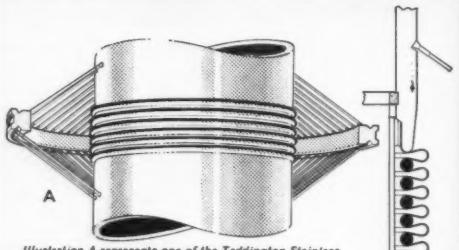


Illustration A represents one of the Teddington Stainless Steel Bellows supplied to Trawsfynydd with a novel form of restraint designed by Richardsons, Westgarth & Co. Ltd. (a member of Atomic Power Constructions Ltd.). This avoids the use of highly stressed hinge pins and permits a complete gimbal movement.

Illustration B indicates a section of Teddington Bellows, showing the restraining rings for extra strength which are a feature of this bellows design.

NO LESS THAN 84 BELLOWS 66″ diameter and 36 BELLOWS 42″ diameter, all of butt-welded stainless steel manufacture, are being fitted at Trawsfynydd to take up movement in the CO_2 cooling gas ducts.

Teddington secured this order only after many exhaustive tests including an accelerated life test equivalent to 20 years full operation. In addition, the larger size bellows were subjected to over-pressure tests of 1580 p.s.i.g. without developing a leak. Wherever pipe-work is subjected to vibration and movement in any direction owing to conditions of temperature and pressure, a Teddington bellows with a suitable end fitting will solve the problem. Write for full details of our range.

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(INDUSTRIAL BELLOWS DIVISION),
AMMANFORD, CARMS.

Made under Licence from the Solar Aircraft Co. California, U.S.A.

Rubberised Fabric for Tanks

POWER COMPANIES IN THE U.S.A. have found the answer to the problem of "drum-juggling" and rigid tank hauling involved in the maintenance of oil-bearing substation transformers and circuit breakers. They are using large collapsible tanks made of rubberised fabric, in place of steel drums or metal tanks, to store oil during periods of repair and routine overhaul.

Hundreds of gallons of oil must be drained from circuit breakers and transformers before any work can be performed on their integral parts. Until the advent of the Pillow tanks, manufactured by The Goodyear Tire and Rubber Co., of Akron, Ohio, the oil had to be drained into individual 50-gallon drums or truck-mounted metal tanks. At the completion of the job, the oil had to be pumped back into the unit.

Many substations are established in remote areas, inaccessible to huge tank trucks. A Pillow tank, compactly rolled and carried in the back of a pickup truck, provides a practical answer to the problem. When dealing with power units that hold more than 10,000 gallons of oil, it becomes a time-consuming and sometimes backbreaking task to remove the oil.

Now, workmen merely roll out a flat Pillow tank, pump the oil into it, do the necessary repair work and pump the oil back into the transformer or circuit breaker. The use of these tanks cuts by almost two-thirds the time previously required to drain and refill the big power units. This is substantial saving, especially in an emergency situation.

Floors Redesigned to Meet Onslaught of Stiletto Heels

EVEN AEROPLANE DESIGNERS are now being confronted with the problem of damage caused by the latest feminine style of stiletto-heeled shoes, and to counter the onslaught of these supersharp spikes the Boeing Co., in the U.S.A., has designed a new floor for its 707 jet airliners.

Hitherto, aluminium honeycomb had been used for the passenger cabin floors of the Boeing 707, and this material had stood up well to normal pedestrian traffic. With the advent of the new style, however, the punishing jabs inflicted by each dainty little round ¼-in. heel, representing, on the shoe of a 110-lb. female, an impact of considerably more than 2,240 lb. p.s.i. load pressure, soon broke down the edges of the honeycomb cells just below the contact surface, and punched dimples into the panel's upper surface.

Before deciding on the type of material to be used for the new floor panels, Boeing tested as many as fifty different combinations of flooring, carpeting and insulation. This was done by means of a specially constructed piece of equipment rather like the sheepsfoot roller used in road construction, which simulated the punishment inflicted by the stiletto heels. Spikes mounted around the roller made random impact on the panel sections, pad and carpet under test, such as would be used on the aisle and between-seats floor of the aeroplane passenger compartment.

A Boeing Co. secretary demonstrating the impact of a stiletto heel on aeroplane flooring. In the background is a specially designed panel testing machine which simulates the damage caused by the sharp heels.

As a result of the test, new stiletto-heel resistant floor panels of corrugated aluminium sheets spotwelded to upper surface skins will replace the honeycomb sandwich on 707 jet airliners now in production, and will be provided to airlines as spares for replacement on an attrition basis.

Weighing about the same as the panels they replace, at about 0.81 lb. per sq. ft., the new corrugated panels are expected to last about eight times as long. They are repairable with materials and methods available to any airline. The heat transmission of the panels is about equal to that of the honeycomb panels, while the sound transmission is less.

Machine Tools Operated by Remote Control

BRITISH ELECTRONICS AND HYDRAULICS EXPERTS have started work on a scheme to operate a machine shop by remote control. Operators watching T.V. screens in a control room some distance away will be able to carry out high-precision machining operations by turning knobs on a small control panel. Full details of the scheme cannot be released for security reasons, but it is being carried out under a contract awarded by a Government department to Armstrong Whitworth Equipment, the Gloucester unit of Sir W. G. Armstrong Whitworth Aircraft Ltd., a member of the Hawker Siddeley Group.

The machines have to be remotely controlled because of unsuitable working conditions for the operators. If necessary, the control room can be several miles away from the machine shop. Although specially built for specific machining operations, the machines to be controlled are basically conventional precision tools. A similar scheme could easily be applied to standard workshop hydraulically-operated tools.

The basis of the scheme will be the electro-hydraulic servo valve, developed by A.W.E. as an industrial unit. This responsive device converts tiny electrical impulses into powerful hydraulic forces. The electro-hydraulic servo valve, together with associated precision actuator jacks, has already been installed, under contract to the Ministry of Works, in the National Gas Turbine Establishment's high altitude test cell at Pyestock. In this installation, the valves and jacks are used in the automatic, programmed and manual control of a series of large butterfly valves, ranging from 12-48 in. in diameter, which control the high-pressure air supply to the test cell.

THE FEBRUARY ISSUE

of *Engineering Materials and Design* will include the following main features:

The Harmonic Drive
Describing a new class of constant-ratio mechanical drive.

Laminates with Inorganic Fillers
Survey of properties and uses.

Insulation of Windings for Traction Machines: Part I
Dealing mainly with a special technique for the production of coils to a predetermined size.

Ballizing with a hand press.

Ballizing of Holes

BALLIZING is a fast, low-cost process for sizing and finishing holes in metal. It consists of pressing a suitably oversize precision ball through the unfinished hole, and requires only the simplest tooling. It is said to bring holes to size in seconds, with high precision and fine finish.

Unlike other hole-finishing processes, ballizing does not remove metal. Instead, it works by a burnishing action, refining the surface structure and leaving a layer of denser metal. The base material is disturbed very little, and acts as a matrix or cushion into which tool marks, waviness and other surface imperfections are pressed by the advancing ball. The hole assumes much of the ball's smoothness, and at the same time is brought to the required diameter.

Ballizing is used successfully for holes ranging from 0.020-5 in. in diameter, but best results are said to be obtained with diameters of 1/16-1 in. The process is claimed to be practically foolproof—the operator merely places the part in a fixture, positions the ball, and starts a ram to push the ball through the hole. Unskilled labour can be used, as accuracy is governed entirely by the size and quality of the ball, not by the skill of the operator or by the adjustment of work or tools. There is no "down-time" for tool sharpening or replacement, and the balls can be inspected or replaced without stopping production.

While the process itself is extremely simple, considerable research has had to be conducted into the development of this technique. Results hinge on the use of specially sized and finished balls. The benefits of this experience, together with advice on each application, will be made available to those interested. Further details of this production process, developed by Industrial Tectonics Inc., U.S.A., are available from the U.K. distributors, Insley Industrial Supply Co. Ltd.

Association of Cost Engineers

A BRITISH GROUP of the American Association of Cost Engineers has been established, with the same objectives as the parent organisation. These are:

1. To advance the science and art of cost engineering.
2. To provide forums and media through which experience with the principles and techniques of cost engineering may be reported, discussed, and published for the common good.
3. To promote standardisation of terminology in cost engineering, and so far as is practicable to develop standard methods.
4. To encourage instruction in cost engineering in standard engineering curricula.
5. To co-operate with other organisations having common interests.

Cost Engineering is defined by the Association as the application of scientific principles and techniques to problems of cost estimation, cost control, and profitability.

An important function of the A.A.C.E. in the U.S.A. is the collection and dissemination of cost data, and the development of improved methods for accurately and rapidly making estimates of capital costs, and profitability.

Operation Cryogenics

OPERATION CRYOGENICS was the name given to a full scale test of a new alloy steel developed by The International Nickel Co. Inc. for the storage and handling of liquids at very low temperatures.

It is known that many steels, although tough and strong at room temperature, become excessively brittle when cooled to sub-zero temperatures. It is also known that the presence of nickel greatly improves the toughness of steels down to temperatures as low as −200 deg. C. The rapid increase in the use of liquified gases like oxygen, nitrogen and methane, involving service temperatures of the order of −200 deg. C., has quickly focused attention upon the need for materials for handling them with safety and economy.

The newly developed 9 per cent nickel alloy steel has passed all the laboratory tests, but as a practical demonstration of its suitability, three companies joined in organising a full scale experiment which involved subjecting a welded rectangular tank, similar in design to those that would be used to transport methane in sea-going tankers, to repeated blows, up to and slightly exceeding 80,000 ft. lb. from a 2-ton steel ball. In this test, liquid nitrogen was pumped into the tank to cool it to −196 deg. C. The test also involved subjecting a 4 x 13 ft. cylindrical tank, similar in design to one which would be used for land-based storage or transportation of liquid gases, to a pressure several times greater than its designed strength, and then pressurising to failure to enable the type of fracture to be examined.

300 guests from many countries, each with a special interest in cryogenics, saw the tests carried out recently with complete success at Fairless Hills, Pennsylvania.

New Paint Testing Technique

A NEW AND UNIQUE METHOD of studying chemical changes in paints and other exterior coatings during outdoor exposure has been developed by The Goodyear Tire & Rubber Co. This method permits the compounding of more durable paint materials, because it allows a more accurate evaluation of molecular changes during outdoor exposure. Previously, such studies were confined to laboratory infra-red tests, which utilized coated salt blocks. Because of the blocks' moisture sensitivity, this technique could not be used outdoors.

Goodyear's new testing method uses the spectrum (molecular finger print) of coating materials deposited on highly reflective aluminium or tin-plated steel panels. The spectrum is recorded by an infra-red spectrophotometer before, during, and after completion of outdoor exposure. Measurements are made directly from the coated panels by means of a reflector on the spectrophotometer, and from the changes noted, the weathering rate is accurately measured.

FOR FURTHER INFORMATION:—

High Duty Alloys Ltd., Slough, Bucks.
The English Electric Co. Ltd., English Electric House, Strand, London, W.C.2.
British Insulated Callender's Cables Ltd., 21 Bloomsbury Street, London, W.C.1.
The Goodyear Tyre & Rubber Co. (G.B.) Ltd., Bushbury, Wolverhampton.
Hawker Siddeley Group PDA Ltd., 10 Bruton Street, London, W.1.
Insley Industrial Supply Co. Ltd., 21-22 Poland Street London, W.1.
Association of Cost Engineers, G. Kirby, 169 Clarence Crescent, London, S.W.4.
The Mond Nickel Co. Ltd., Thames House, Millbank, London, S.W.1.

SETTING AN EXAMPLE

Mr. B. E. Monck

Setting an example is an important aspect of everyday life. Young people instinctively follow the example of their elders, and a great responsibility is therefore placed on the shoulders of parents and teachers—a greater responsibility than is sometimes realized. This tendency to follow the example of others is not common only to young people. The majority of us find ourselves behaving, to some degree, in a similar way to those with whom we are in daily contact.

Setting a good example and gaining respect and admiration go hand-in-hand, and an employer who attains those qualities will be amply repaid by the increased efficiency of his staff, quite apart from the inner satisfaction he will enjoy in the knowledge that he is conducting himself in a manner befitting his position. An employer who consistently strolls into his office at 10 a.m., takes two hours for lunch-time refreshment, and spends two or three afternoons a week on the golf course, can hardly expect his staff to be willing workers and conscientious time-keepers.

The reward of setting a good example is apparent at Spicers' Stationery Factory at Sawston, where cleanliness and tidiness of the entire estate is particularly noticeable. The reason is obvious when it is learned that the general manager (B. E. Monck) is never too busy or preoccupied to pick up a piece of paper blowing about in the yard and place it in the nearest receptacle. The employees follow suit without being told. Indeed, if they were instructed in this respect, it would go in one ear and out of the other.

We all like to feel that we play an important part in the industry in which we work. This feeling of "belonging" is encouraged at Spicers in many ways. Each department has a notice board on which the daily output figures and bonus earnings are displayed. In this way, the employees can rejoice with the management and be spurred on to greater achievements when the figures are high, and will work conscientiously to improve matters should the figures occasionally fall below the target. When methods are altered in the interest of greater efficiency, the reasons for the modifications are explained to the workers involved. Thus, an alteration in routine which may have been viewed as a tiresome and irksome piece of red tape, becomes a welcome suggestion resulting in increased bonus figures appearing on the notice board.

The delicate balance between warm-hearted friendliness and an over "chummy" attitude resulting in lack of respect is not easy to attain, but well worth aiming at. The management at Spicers are well rewarded for achieving this balance in many ways, the most obvious being the fact that production rose from 1957 to 1959 far ahead of the national average for the U.K. paper industry, and was, in 1959, roughly 17 per cent higher than two years previously. The increase in the national average in the same period was only 6 per cent.

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Applications, which will be treated in confidence, should give full personal particulars and details of past and present experience and present level of remuneration to:— The Chairman, Brooke Marine Limited, Tallington, Stamford, Lincs.

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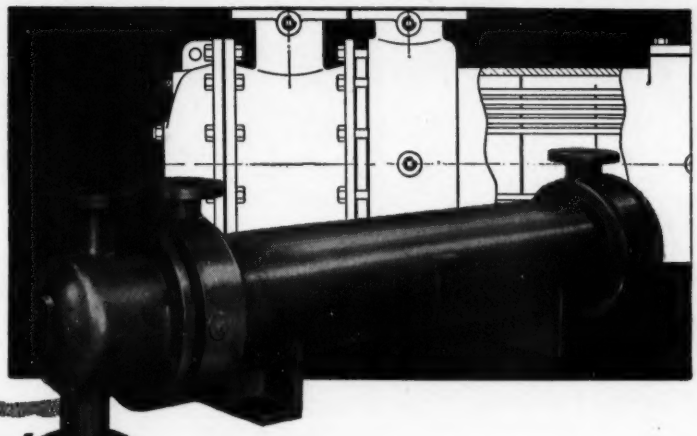

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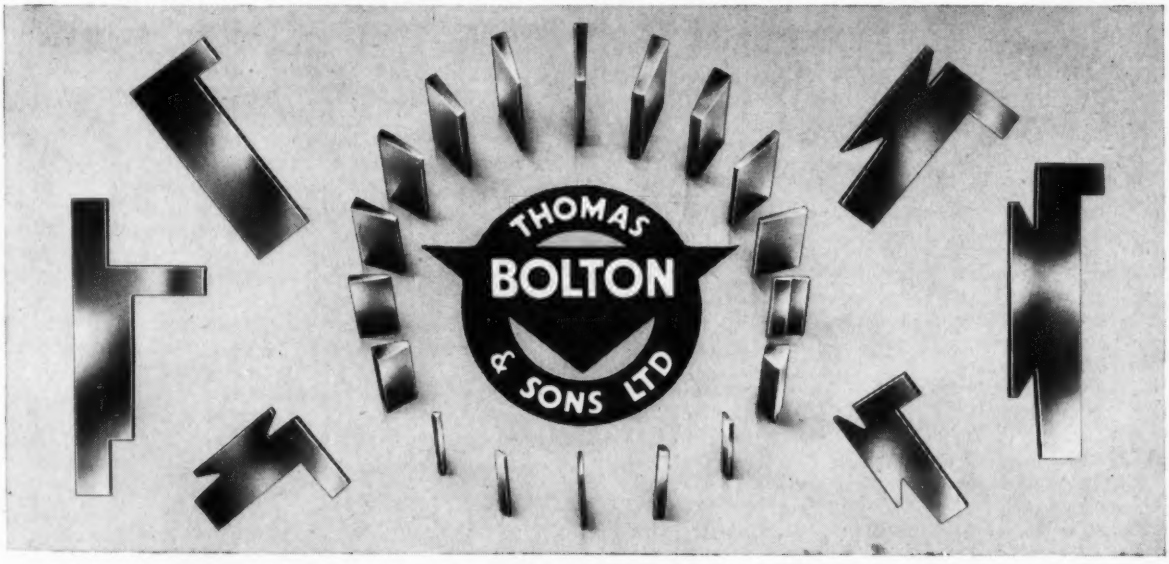

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MA2

FUEL CELLS OR STEAM ENGINE ?

THE current interest in fuel cells is not merely a fashion, but the result of a genuine enthusiasm which engineers have for any new system of energy conversion. This enthusiasm is partly due to the enormous possibilities which would open up in the field of transport if a cheap, lightweight electric generator could be developed. Professor Owen A. Saunders, in a recent paper to the Institution of Mechanical Engineers, pointed out that new machines tend to be more complicated than the older ones they displace, and it is rare for the new machine to be simpler, as in the transition from the piston engine to the aircraft gas turbine. He believes that this fact has led to the extraordinarily rapid change-over to gas turbines, which, despite their novelty, have reached a high standard of reliability in a much shorter time than did the piston engine. If fuel cells were to become a practicable and economic proposition, the simplicity of electric traction for road vehicles would result in a similar rapid change-over from the i.c. engine.

Enthusiasm for fuel cell technology is therefore understandable, but should not be allowed to cloud the practical realities. Dr. H. H. Chambers, of the Sondes Place Research Institute, in a paper given at the Second International Symposium on Batteries, referred to "Fuel Cellsmanship", implying that publicity had jumped ahead of the technical development. In his paper on "General-purpose Fuel Cells", Dr. Chambers pointed out that most investigators had concentrated on high-temperature cells, which do not require such active electrodes as the low-temperature cells, nor specially purified fuel gas. The most advanced cell of this type is undoubtedly the one pioneered by Francis Bacon, but it operates at 200 deg. C., and therefore is not practicable for road vehicle application, owing to the warming-up period required before starting. Furthermore, the control equipment required for this cell is considerable, so that by comparison the steam car, which still retains its group of enthusiasts, is a better proposition than the fuel-cell-powered vehicle.

Whilst appreciating the scientific reasons for Dr. Chambers' view that research should be aimed at high-temperature cells, the practical engineering approach is very much concerned with the overall unit including control gear. The achievement of a very high cell output in amp./sq. ft. of electrode is all very well as a scientific experiment, but the commercial exploitation of fuel cells might be more straightforward if more attention was paid to room temperature devices, where the lower specific output would be more than offset by reduced complexity, weight and volume.

Fuel cell technology is now the subject of a major research effort, at least five organisations having declared their activities in this country. In the U.S.A. some twenty-five companies are involved, and progress has also been reported in the U.S.S.R., Holland and Germany. The latest organisation to announce its entry into this field is the Battelle Memorial Institute, which has a long-term research programme aimed at a better understanding of the properties of materials required in a cell, and the development of special materials which approach the ideal. This effort is supported by major American and European industrial organisations, including chemical, petroleum, transportation, mechanical equipment, public utilities, and engine and automotive manufacturing companies. It will be surprising indeed if a practical fuel does not evolve from all this work. Although it seems that a major invention is still needed, it would be dangerous to conclude at this stage that such a step is unlikely, for in the same way that the transistor has revolutionised the electronics industry, so a new active material might spark off the commercial exploitation of a low-temperature fuel cell.

In the meantime, engineers who wish to assess the present position of fuel cell development compared to well-known batteries could do worse than read an excellent booklet written recently by Dr. M. Barak of the Chloride Electrical Storage Co. (see page 63). His guess is that at least another five years will elapse before fuel cells seriously rival the lead-acid battery, which still holds it own for portable propulsion units.

The Editor

CELLULAR PLASTICS

Of the many hundreds of individual polymers which have been developed, fewer than one dozen have achieved commercial importance as cellular plastics—the preparation, properties and uses of these are described here

by L. N. PHILLIPS, A.R.I.C., F.P.I. *

DURING the past twenty years—and particularly since the war—there has been a great increase in the use of low-density materials. They are finding application in direct competition with traditional substances such as cork, pith, balsa and felt; and also in new fields which have not been exploited previously, because of the ease with which these natural products are affected by water absorption and fungal attack.

For success, a method of expansion must be found yielding a uniform product, preferably in a range of densities, and with close weight control at any selected density. The overall combination of physical and chemical properties must be so different from existing cellular materials that applications will be found in the face of this competition.

Methods of Expansion

Both chemical and physical methods of expansion are employed. In the former method, a gas such as nitrogen, carbon dioxide or hydrogen is produced, either by thermal decomposition of an unstable blowing-agent, or by direct reaction between chemical groups of the plastics and its hardener. In physical methods of expansion: (a) gas may be dissolved in a liquid plastics under pressure and released later; (b) volatile liquids such as Freon may be vaporised at elevated temperature; or (c) air may be beaten into a liquid resin to form a liquid foam which is then allowed to harden. A different method, of increasing importance, is to fuse together a thermoplastics and a finely divided material such as soluble starch, which is afterwards leached from the product by a washing process.

This approach is reversed in the final method. Hollow, microscopic bubbles of resin are cemented together with adhesive so as to yield a composite low-density body.

These last three techniques, whereby voids are introduced into a plastics, are different from previous methods, inasmuch as there is an absence of *expansion during a plastic state*. It is the latter type of expansion which causes two-dimensional stretching of the cell wall, and there is little doubt that some plastics, such as polystyrene, which are brittle in the massive form are much tougher because of this orientation in the expanded state.

* *Chemistry Department, Royal Aircraft Establishment, Farnborough.*

Table 1 gives a list of the common types of cellular plastics and their methods of production. Rigid expanded Hycar is included in the discussion because of its many similarities to the cellular plastics, though the various forms of cellular natural rubber have been omitted.

The Process of Selection

In selecting a cellular plastics for technical use, the designer should ask three questions of fundamental importance:

Is the material of closed-cell construction or are the cells primarily interconnected?

Products of the closed-cell type have a very low water absorption, even after prolonged immersion. They are immediate candidates for flotation and buoyancy gear. The open-cell type of foam tends slowly to increase in weight, though a great deal can be done to prevent this by using sealed containers or applying an impervious coating to the surface. Some types of open-cell foam contain a proportion of closed cells, so that there is some buoyancy even at saturation.

All types of cellular plastics are good insulators against heat and cold because of the innumerable pockets of air or gas that the cells enclose. Where an open-cell foam surrounds the cold source, and where there is continued cycling between extreme cold and room temperature, water vapour may finally condense as ice within the innermost cells and reduce the thermal efficiency. These conditions apply in both domestic and commercial refrigeration, so that, other things being equal, a closed-cell construction is preferred.

In the field of protective packaging one distingushes between the package with a continued life and the expendable pack which is used once only, as in supply-dropping operations. In the latter case the crash-pad will give a different load-compression curve if the air is trapped within the cells than when it can escape freely on impact because of an open-cell construction.

Cushioning, in the upholstery trade, consumes an enormous amount of foamed material. The human subject prefers a "soft" cushion, i.e., one which experiences considerable initial deflection under low stress. For this purpose an open-cell structure is required, since a closed-

cell material has an almost linear stress/strain curve in compression.

Is the material of the thermosetting or the thermoplastic type?

There is a marked difference in behaviour on heating between the linear thermoplastics foams and the cross-linked thermosetting ones. As the temperature approaches the softening point of a thermoplastics foam, the elastic memory becomes evident, and marked shrinkage and cell collapse may occur even in the absence of an external stress. In a thermoset material, where cross-linking is completed *during or after cell formation*, there is a tendency to retain the cellular form in the unstressed condition but to experience a decrease in load-carrying capacity when stressed. The designer, when interpreting data for softening point or maximum operating temperature, should remember that these usually refer to the unstressed condition. Two examples will illustrate the point. A cross-linked rigid polyurethane foam may be an efficient heat insulator at 150 deg. C., but have lost over one-half of its room-temperature compressive strength at 120 deg. C. Again, a silicone foam is soft and easily deformed at 180 deg. C., but will retain its shape if unstressed at 280 deg. C. for prolonged periods.

At sub-zero temperatures, all rigid plastics lose a little in impact strength and gain a little in tensile strength, as compared with room-temperature values. These effects balance each other, and the performance of rigid cellular plastics remains satisfactory at low temperatures. The evidence from the many successful applications in refrigeration equipment and sandwich structures intended for arctic conditions is that there are no special structural design problems due to material changes at sub-zero temperatures.

Can the plastics be expanded by the user, or must he obtain pre-moulded material?

Many of the commercial methods of expansion involve a stage requiring considerable heat and pressure, or expensive equipment. In such cases, the user buys pre-expanded material as rod or sheet stock, from which the required components are made by hot-forming, machining, welding or gluing. Fabrication by such methods is well established for many relatively simple shapes. Where complex shapes or considerable accuracy is needed, there is often an advantage in foaming-in-place; indeed, in many cases it is the only method of doing the job.

Since so many new applications of cellular plastics depend on the production of foam *in situ*, an outline of some of the different procedures is given.

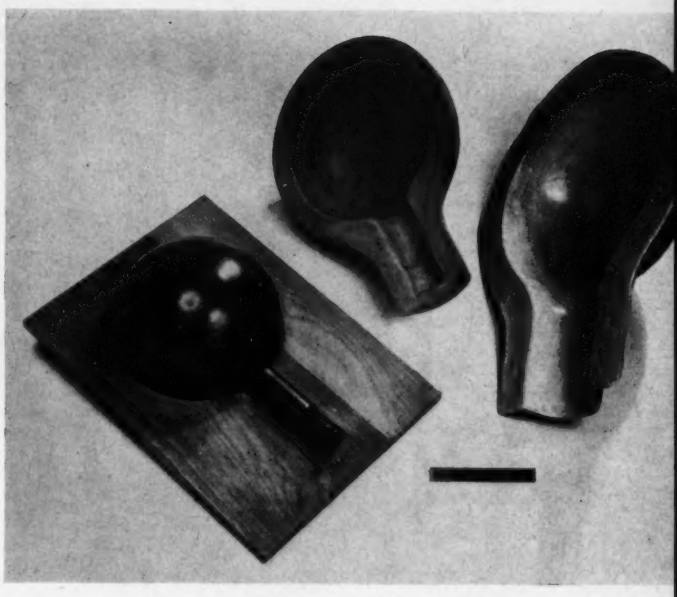


Fig. 1. This flask insulator (centre) was made by foaming-in-place between the left- and right-hand mould halves with polyurethane.

(a) Emulsion polymerised beads of polystyrene containing a blowing agent are partly expanded by infra-red heating, or by a brief immersion in water held at 95 deg. C. These pre-expanded granules are closely packed into a mould and heated rapidly by injection of live steam or immersion of the mould in boiling water. Softening and further expansion of the granules causes them to weld together into a single structure.

(b) A thermosetting silicone resin, filler and blowing agent are ground together to form a fine powder. This is spread evenly across the bottom of a mould and heated at 180 deg. C. for 3 hr. A steady increase in volume occurs, the foam finally having a density of 12·1 lb./ft.^{3}

(c) A liquid alkyd resin, containing a bubble modifier and catalyst, is mixed with a liquid di-isocyanate. Within a few minutes foaming begins, and the creamy mixture is

Table 1. Plastics materials which produce commercial foams

Base Polymer	*Method of Expansion*	*Cell Construction*	*Type of Molecular Structure*	*Forms Available*
Polystyrene	blowing agent	closed	thermoplastic	Moulded components and extruded board.
Polyvinyl chloride	(a) blowing agent (b) leaching	closed or open open	thermoplastic	Slab stock, moulded shapes, thin sheets by leaching.
Polyethylene	(a) blowing agent (b) leaching	closed open	thermoplastic	Extruded sections and moulded components, thin sheet by leaching.
Cellulose acetate	volatile solvent	closed	thermoplastic	Boards and rod stock produced by extrusion.
Hycar synthetic rubber	blowing agent	closed	thermosetting	Sheet stock by moulding.
Epoxy	(a) blowing agent (b) mixed with micro-balloons	closed	thermosetting	Slab stock and individual shapes.
Phenol/formaldehyde	blowing agent	closed	thermosetting	Individual shapes, and cavity filling by foaming-in-place.
Urea/formaldehyde	(a) solvent removal (b) air whipped in	open	thermosetting	Slab stock usual, cast shapes possible.
Silicone	blowing agent	closed	thermosetting	Individual shapes by foaming-in-place.
Polyurethane	Chemical production of carbon dioxide	rigid foam primarily closed, flexible foam primarily open	thermosetting	Slab stock, thin sheet by splitting. Individual shapes by foaming-in-place.

poured into a glass fibre-polyester resin shell previously primed with adhesive. As the material continues to expand, it presses against the tacky adhesive and gives an extremely good bond. Excess foam is expelled through venting holes at the top of the moulding.

(d) The alkyd/di-isocyanate mixture prepared as in (c) is strongly cooled with dry ice before expansion takes place. The resulting brittle solid is finely powdered, and weighed amounts are carefully measured into a series of moulds, each containing an electronic assembly. On returning to room temperature, foaming begins as before.

(e) A liquid epoxy resin, catalysed with a hot-setting aromatic diamine, is added with stirring to twice the weight of phenolic resin micro-balloons. The product, similar in appearance to damp sand, is packed into a metal mould coated with parting agent. Cure takes place in an oven for 3 hr. at 140 deg. C.

(f) A polyether/di-isocyanate mixture is atomised and blended, in a twin-nozzle spray gun, with an aqueous activator solution. As the spray strikes the target, rapid expansion begins and a continuous layer of foam approximately 1 in. thick is formed. This is primarily of closed-cell construction.

Physical Properties

The most important physical properties of cellular plastics are given in Table 2. Three general observations should be made which are of interest to designers.

There is often an orientation effect during expansion, so that the strength of the foam varies in different directions. Resins which are foamed-in-place within long narrow cavities experience drag against the walls of the cavity. The resulting shear forces cause elongation of the cells.

A very common use of cellular plastics is as the core of a sandwich structure. Any reduction in compressive strength *normal to the facing skins* must be allowed for (see Fig. 5).

The third point is that cellular plastics get progressively weaker on a weight-for-weight basis as the specific gravity decreases. This is well illustrated in Fig. 4, where the compressive strength is plotted against density for a rigid polyurethane foam. The reason for this reduction in efficiency is that as the foam is expanded further the cell walls become progressively thinner, and buckling failure occurs more readily. The designer must not expect high absolute values or high specific values for the mechanical properties of cellular plastics at densities below about 4 lb./ft.^{3} The Owens-Corning manual is helpful to the designer in selecting the optimum dimensions for panels in different types of sandwich construction.

Table 2 does not indicate the machinability of cellular plastics, and the point is mentioned below in the discussion on individual materials.

Applications

It is rare for a cellular plastics to be chosen for a particular application because of one specific property. Like other engineering materials, cellular plastics are chosen because of a suitable combination of properties. New end uses arise from the demands of the engineer, and also from the efforts of materials producers to create larger markets for their products. The reader will appreciate that the examples mentioned in connection with specific materials represent the best economic and technical solution to the design problem. Often the use of alternative materials is technically *possible* but less desirable in practice.

POLYSTYRENE—Polystyrene foam has become widely used since the introduction of "expandable-bead" and extrusion methods of production. Very uniform closed-cell products are obtained, having densities as low as 1·0 lb./ft.^{3} The water absorption is very low, and there is no deterioration on prolonged immersion, so that polystyrene foam is popular for life-belts, life-rafts and other kinds of floating gear. In many cases lightweight foam is used as built-in buoyancy in small craft instead of the more vulnerable buoyancy bags.

Polystyrene foam has a favourable K value, and is used for many kinds of insulation. It is used for reducing heat losses in chemical plant, in cold-storage warehouses, and in factories.

The material is an efficient shock absorber, and finds employment in certain types of crash-helmet and in many types of packaging.

Normal woodworking tools can be used for fabricating polystyrene foam. With the product made from expandable granules, it is difficult to produce a perfectly smooth surface by machining, because of occasional breakaway at the weld-line of individual grains.

A limitation to the use of polystyrene is its liability to ready attack by solvents such as chlorinated hydrocarbons, ketones and esters, which are found in many commercial adhesives. Special adhesive formulations are available for gluing polystyrene foam correctly. Styrene monomer, the vinyl derivative found in most polyester resins as the cross-linking agent, also attacks polystyrene foam, and the surface of the latter must be sealed before laminating with polyesters. The foam is thermoplastic, and should not be

Fig. 2. Foamed parts made by packing an epoxy resin-microballoons mix round the central rod (the mould is shown at the bottom of the picture).

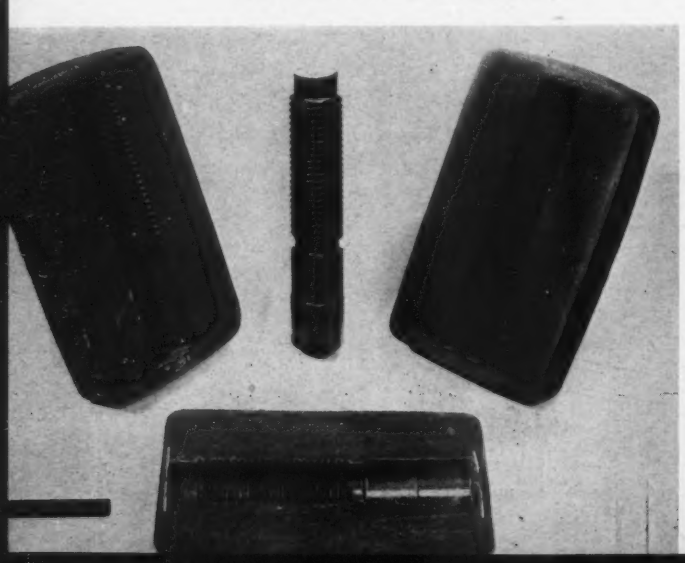
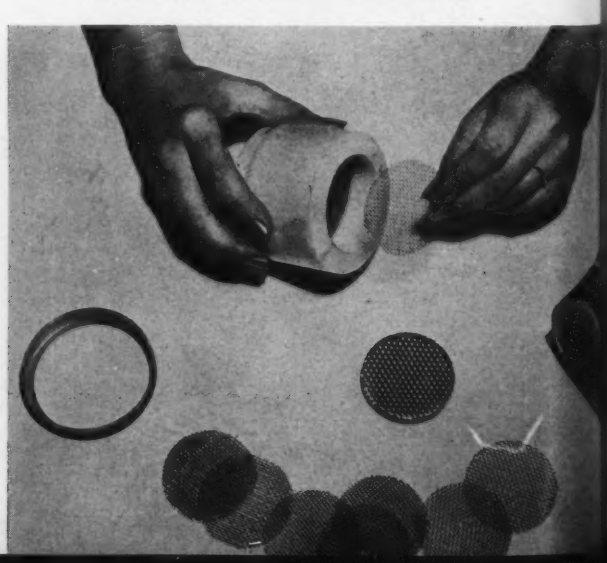


Fig. 3. A semi-rigid urethane shell is used for this respirator, which is claimed to be suitable for temperatures up to 150 deg. C. (Allied Chemical International).



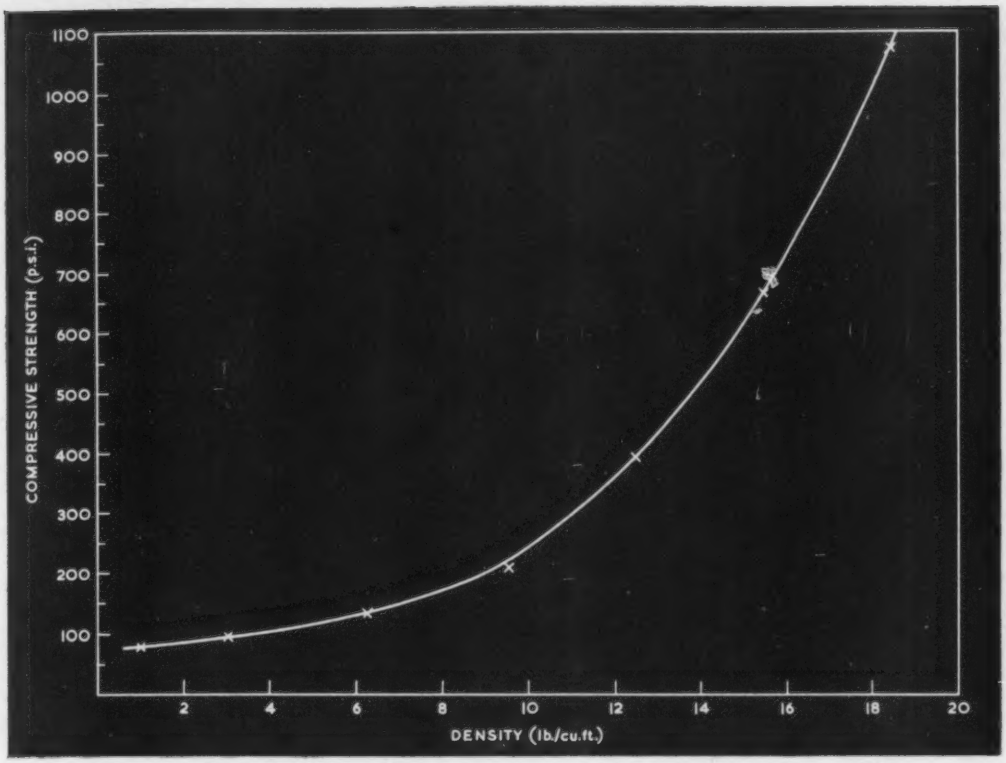


Fig. 4. Compressive strength plotted against density, for rigid closed-cell foams.

used at temperatures over 70 deg. C. This temperature is sufficiently high to enable the material to function in sandwich panels for curtain walls in building construction.

POLYVINYL CHLORIDE—Polyvinyl chloride foam is available in both rigid and flexible formulations, the latter being either open- or closed-cell construction. The flexible open-cell product is a competitor to latex rubber and polyurethane foam in upholstery applications. Continuous methods of production have been developed. The flexible foam is readily welded by dielectric heating.

Rigid polyvinyl chloride foam is tough, will not support combustion, and is easily hot-formed using hot water as the heating medium. It is more expensive than polystyrene foam, but is inherently flame-resistant. Comparatively few solvents, mostly chlorinated hydrocarbons, will attack polyvinyl chloride foam. At densities over 2 lb./ft.^{3} the material is resistant to styrene monomers, and direct lamination with polyester resins is possible.

The rigid foam is a delightful material to work with ordinary woodworking tools. Extremely thin sections and feather edges are readily produced. Uses include buoyancy gear such as fishing floats and life-jackets, and a new type of life-boat. The thermal conductivity is low, and many uses in low-temperature insulation are found.

Rigid microporous p.v.c. (Porvic) is most successful as a plate separator in car batteries and other heavy-duty accumulators. In this application an open-cell structure is required.

POLYETHYLENE—Until comparatively recently, polyethylene was an expensive thermoplastics. The expansion achieved during the foaming process was limited, so that the *volume* of foam per pound sterling was low. The main applications to date of this type of low-expansion closed-cell polyethylene foam are as a low-loss co-axial cable for radar and television purposes, and for floating or underwater telephone cable.

Now that polyethylene has become one of the cheapest plastics, because of large-scale production, one may expect a movement towards more general uses of foamed material. Buoyancy gear such as fishing floats would seem an appropriate outlet. One particular form of high-density polyethylene is made by the leaching process; a microporous material (Vyon) which is an extremely useful filtration medium is obtained. Vyon is unaffected by almost all chemicals, even at elevated temperatures.

CELLULOSE ACETATE—The Strux Corp., in the U.S.A., working under licence from the Du Pont Co., produce cellular cellulose acetate in the form of extruded board and rod stock. A tough, closed-cell foam is produced which has the highest softening point of all commercially available thermoplastic foams. It can be used at temperatures over 100 deg. C., where polystyrene and polyvinyl chloride foams are useless. The material is used as a core in sandwich constructions, the facing skins being of plywood, metal or glass-fibre polyester resin laminates.

A particular use of cellular cellulose acetate is for gun-port plugs on U.S. military aircraft. The plug disintegrates on firing, the debris causing no blade damage on passing through the jet engine.

HYCAR—Expanded Hycar is marketed in the form of flat board of closed-cell construction. It is widely used as a core material in radome construction, because of its low moisture absorption, small power factor, and the ease with which it can be hot-formed into double curvatures. In polyester resin bonded laminates, cleaning and sealing of the Hycar is recommended in order to get good adhesion. This extra step is not required where laminates are bonded with epoxy resins.

Expanded Hycar is an efficient thermal insulator with an upper temperature limit of 100 deg. C. A recent example of its use was the pipeline insulation for the installation handling liquid methane imported by the National Coal

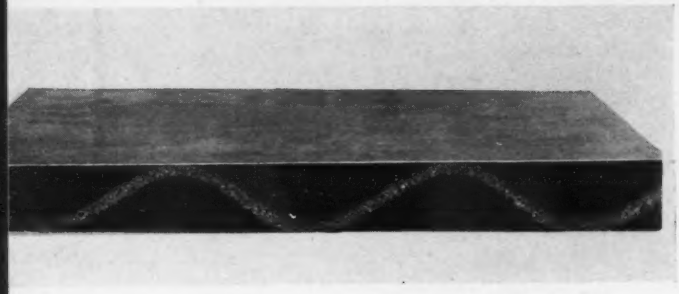


Fig. 5. Aluminium laminate with a core of corrugated p.v.c. foam (Microcell Ltd.).

Board. The material is readily worked, but the characteristic smell produced on machining Hycar is sometimes objected to.

EPOXY RESINS—Liquid epoxy resins have not been widely used so far for foamed-in-place applications. The expansion is difficult to control, since it depends on the degree of exotherm produced by the resin-catalyst mixture. Where the time and temperature of cure can be rigidly controlled, sizeable blocks of epoxy resin foam can be produced. These find some application in toolroom practice and prototype construction, since the texture is uniform, the material is easily worked, and the dimensional stability is excellent.

An increasing use for epoxy resins is as a binder for phenolic resin microballoons in the manufacture of so-called "syntactic" foam. Either hot-setting or cold-setting formulations can be used. The resin-microballoons mixture resembles damp sand or putty, depending on the ratio of binder to filler. The mix can be worked either by trowelling into position or by packing into a suitable mould where curing occurs. A resin-microballoon system with cold-setting catalyst is one of the simplest ways of producing individual components, since a balance is the only equipment needed (see Fig. 2).

In the patented Dow process a cold-setting epoxy resin is mixed with a quantity of expandable polystyrene beads. The beads are warmed by the exotherm from the epoxy resin, and as they grow they squeeze the resin towards the outside of the mass. A composite foam is produced with a gradation in density from the centre outwards.

PHENOL - FORMALDEHYDE—Liquid phenol - formaldehyde resins are usually expanded by the addition of a carbonate and an acid hardener. A rapid reaction takes place, with generation of a considerable exotherm. The system should not be used in metal components—because of the corrosion risks—unless the metal surface has been fully protected from acid residues. Where reinforced plastics such as melamine-surfaced laminates are used as facing skins, a most attractive sandwich can be produced. Because foaming and gelation take place so quickly—within 15 sec. of mixing—pouring into narrow cavities is difficult. The best results are obtained with automatic mixing equipment filling standard sections with a minimum thickness of about 1½ in. The foam does not burn readily, and has a good resistance to elevated temperatures.

Apart from the normal uses in sandwich construction and as thermal insulation, phenolic resin foam finds application as a lightweight core for jigs, stretch forms and press tools. Here the property of expansion in large self-curing masses shows to advantage.

UREA-FORMALDEHYDE—Extremely light, rather friable foams can be made by the expansion of urea-formaldehyde syrups. The construction is normally open cell, and surface sealing is needed when the material is used for insulation purposes. It does not support combustion. Two non-technical applications familiar to the general public are as a stem-holder in floral displays, and as the artificial "snow" used in theatrical effects.

SILICONE RESIN—Rigid silicone resin foams are produced by controlled heating of a mixture of thermosetting resin, blowing agent and inorganic filler. A temperature of at least 150 deg. C. is required, and 180 deg. C. is normal. The foam is the most thermally stable of those discussed. Prolonged exposure to 300 deg. C., and even short periods at 400 deg. C., do not destroy the structure. In a direct Bunsen flame the material becomes incandescent, but does not ignite; a skeleton of silica is left. There are limitations to the use of rigid silicone foams as the core material in structural sandwich applications. They are brittle and friable at room temperature, and suffer a considerable loss in compressive strength at temperatures of 180 deg. C. or more.

If a purely thermal insulation is required, which can be foamed-in-place and withstand high temperatures, the silicone foams are attractive.

POLYURETHANE FOAMS—Polyurethane foams can be divided into two main classes—the original polyester-based products, and the more recently introduced polyether-based materials. There are important differences in foams derived from these two sources. When a polyether triol is expanded to form a rigid foam of low density (2-4 lb./ft.³), this is of closed-cell construction. A rigid polyester foam at the same density contains a high percentage of open cells. An exception to this generalisation is the case of sprayed poly-

Table 2. Physical properties of commercial cellular plastics

Physical Property	*Polystyrene*	*Polyvinyl chloride*	*Polyethylene*	*Cellulose acetate*	*Hycar*	*Epoxy resin*	*Phenol/formaldehyde*	*Urea/formaldehyde*	*Silicone resin*	*Polyurethane (rigid)*	*Polyurethane (flexible)*
Specific gravity	0.031	0.048	0.47	0.125	0.155	0.21	0.077	0.047	0.187	0.062	0.031
Density (lb./ft.³)	2.0	3.1	30.0	8.0	10.0	13.0	5.0	3.0	12.0	4.0	2.0
Tensile strength (p.s.i.)	55	100	670	180	140	360	35	15	-	75	20
Compressive strength (p.s.i.)	30	55	-	230	140	440	31	20	100	50	0.5 *
Modulus in compression (p.s.i.)	800	1,700	-	13,000	6,000	-	-	-	-	2,000	-
Thermal conductivity (K value)	0.24	0.22	-	0.28	0.25	0.27	0.21	0.24	0.30	0.21	0.24
Thermal expansion (in./°C.)	4.5×10^{-5}	6.1×10^{-5}	-	4.5×10^{-5}	5.0×10^{-5}	2.8×10^{-5}	-	-	-	4.5×10^{-5}	-
Water absorption (% increase by volume)	0.75	0.3	0.02	2.5	0.5	0.1	2.0	14.0	2.5	2.0	90.0 †
Dielectric constant	-	-	1.48	1.12	1.46	-	1.19	-	1.23	1.1	-
Loss factor (10,000 c/s/sec.)	-	-	0.00033	0.003	0.003	-	0.28	-	0.004	0.002	-

* At 2% compression.
† Open cell construction.

ester insulation, where a higher percentage of closed cells results from the rapid catalysis needed to prevent sagging of the foam during the hardening process.

When polyester and polyether diols are expanded to give flexible open-cell foams, there are marked differences in the stress-strain curve in compression, the polyether foams showing greater resilience, and the polyester foams showing a marked "plateau" effect. These characteristics indicate that the polyether-based foams are suitable for upholstery, while the polyester-based materials are more suitable for packaging.

Both rigid and flexible foams are produced in slab form by high-output continuous mixing machines. Specialist processors have developed effective techniques for cutting, welding, hot-wire shaping and gluing, so that a wide variety of component shapes can be fabricated from slab or sheet stock.

Polyurethanes are particularly suitable for foaming-in-place. Several methods are used, depending on the size and number of cavities to be filled and the variation permitted in foam density (see Fig. 1).

For large-scale work such as the filling of ships' rudders and refrigerated hold insulation, portable continuous mixers have been developed. Special on/off mixing heads have been designed by Imperial Chemical Industries Ltd., so that intermittent delivery is possible. A notable reduction in the health hazard has been brought about by the introduction of a liquid technical grade of di-isocyanatodiphenyl methane, instead of the more common toluylene di-isocyanate. Batch methods of mixing are used for smaller scale foaming-in-place operations.

Where close control of density is not required, the liquid alkyd-isocyanate or polyether-isocyanate mixture is allowed to foam freely, any excess being extruded through vent holes at the top of the cavity. For precision foaming, a weighed amount of mixture is injected into the mould, which is then closed to prevent the escape of material. The "frozen-powder" method has already been described above —it is particularly suited to filling a number of very small components with a precise amount of foam.

Flexible foams find application as anti-vibration mountings, as seals and gaskets, and in numerous protective packs. In the clothing industry the polyurethanes are used for shoulder pads, interlayers, and lightweight insulation for cold-weather sportsgear. The material can be stitched without tearing and withstands dry-cleaning fluids. Interior padding and cushioning in automobiles is being increasingly produced from polyurethanes. Appreciable economies result when the mixture is poured directly into vacuum-formed co-polymer sheet and allowed to foam-in-place.

Rigid polyurethane foams are used in many structural and non-structural sandwich applications in the aircraft field. They are becoming very popular for the "potting" of electronic components, where they show a considerable weight saving over solid resin castings. Semi-rigid foams can also be produced, such as the respirator shell shown in Fig. 3.

Sprayed foam is employed for the thermal insulation of aircraft fuselages and various shipboard and factory installations. Recently, closed-cell polyether foams have appeared with volatile fluorocarbons such as Freon added as auxiliary blowing agents. The thermal conductivity of this type of low-density foam is extremely low, and will remain low, provided that escape of gas is prevented by sealing. In submarine construction, heavy closed-cell foam applied by foaming-in-place is used for the filling of dead space. It replaces traditional fabricated timber construction, which it considerably heavier and more costly to install.

Conclusion

In this review, the aim has been to outline the different methods of production of cellular plastics, to describe their physical and chemical properties, and to show how the designer should set about choosing specific foams for particular purposes. Several examples of good commercial practice have been included for study. It is hoped that cellular plastics will the more readily be considered by design engineers, and their correct application increased.

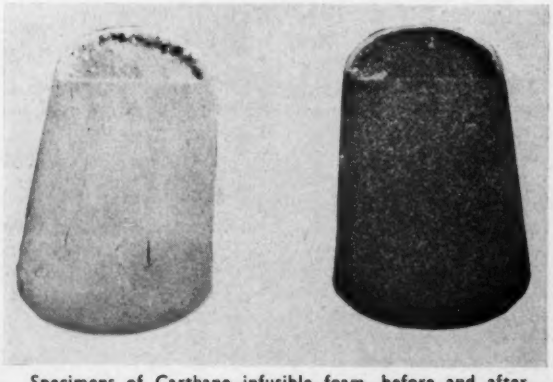
INFUSIBLE RIGID URETHANE FOAMS

RIGID urethane foams that retain from 45 to 65 per cent of their room temperature compressive strength at 320 deg. C., and that cannot be melted, have been developed by the Carwin Co., of Connecticut. Exposed to increasingly higher temperatures, the cellular structure is maintained to about 480-540 deg. C., when the foams slowly begin to carbonise. They then proceed to change directly from the solid to gaseous state, at no point reverting to a liquid or plastic state. Post-curing is required to develop ultimate physical and thermal properties, dimensional stability being maintained to 230 deg. C. Between 230 and 260 deg. C. there is some weight loss, with a degree of shrinkage.

Carthane 1008 infusible foam system rapidly reacts and produces rigid foams that have a relatively high mechanical strength over a wide range of temperatures. The coefficient of thermal conductivity (k) for foam at 160 deg. C. with a density of 3 lb./cu. ft. is only 0·26. Identical properties are found in Carthane 1003 infusible slow foam, which has a controllable pot life of 5-12 min., sufficient for the material to flow into voids of complicated shape before reaction commences. Densities available in these systems range from 3-40 lb./cu. ft.

It has been observed that the rigid low-density foams show extraordinary ability to absorb impact without rebound over a wide range of temperatures, while the low and high frequency vibration-damping properties are also exceptional. Samples of cured foam partially buried for six months in fertile soil showed no appreciable signs of ageing. The dielectric strength and dissipation factors are believed to be retained over the full range of foam densities for a wide range of frequencies and extreme temperatures.

High-temperature-resistant flexible foam systems based on this polymethylene polyphenylisocyanate have also been developed. Applications include structural insulation for high speed aircraft and missiles, shock-resisting and vibration-damping enclosures, and ablation coatings.



Specimens of Carthane infusible foam, before and after curing for 14 hr. at 204 deg. C. Shrinkage and loss in wt. are negligible. Colour gradually changes, becoming a rich brown at the end of the cure.

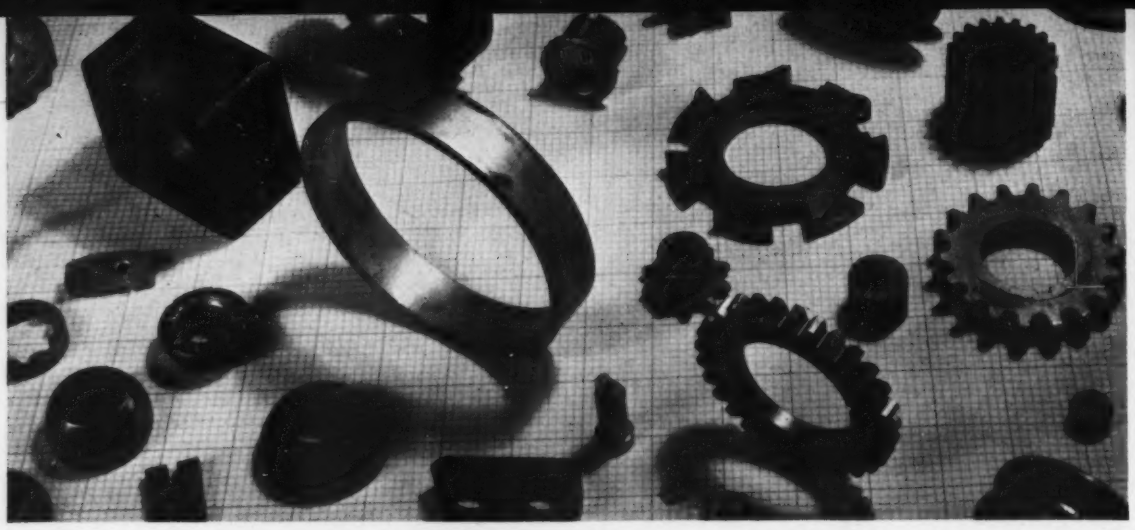


Fig. 1. Typical examples of sintered components in various metals (Sintered Products Ltd.).

SINTERING HELPS THE DESIGNER

This article describes the metal sintering process, and the various factors influencing design. It concludes with a review of some of the more recent developments in powder metallurgy techniques

SINTERING is the term applied to a heating process, although it is common practice to apply it to the processes of compaction and heating in powder metallurgy. Now that sintered plastics, together with sintered filter materials, are on the market, however, it should be borne in mind that sintering and powder metallurgy are not necessarily synonymous.

Sintering converts a raw pressing of small mechanical strength into a product with certain guaranteed mechanical and physical properties. (Typical sintered components are shown in Fig. 1.)

It would be difficult to find an industry where the products of powder metallurgy are not used. It is employed in the production of hard-faced tools and machine products, and in the modern car over 120 parts in different materials are, or could be, made by powder metallurgy techniques, many with self-lubricating properties.

The basis of powder metallurgy, as the name itself implies, is the production of parts or ingots derived mostly from pure metallic powders. Non-metallic powders of chemical elements or compounds, mostly metallic oxides and carbides, are also used. The basic technological phases are: (1) production of the raw material (metallic and non-metallic powders); (2) production of the raw part or ingot (green compact); and (3) sintering at a temperature between 75 and 90 per cent of the melting point of the material.

The closely controlled tolerances which are practicable compare most favourably with precision machined parts. As sinterings are produced from metal powders of closely controlled characteristics, and parts are made from a common set of tools, uniform properties are obtained from batch to batch.

Repressing or sizing of sintered parts may be necessary when very small dimensional tolerances have to be maintained. The operation of coining is also employed to alter the physical characteristics of the compact, and differs from sizing in that the whole of the compact is cold worked to increase its density and to improve the mechanical properties. The compacts are often resintered. Contrary to what is often expected, sintered parts can have considerable ductility, as shown by examples in Fig. 2.

A double-press sinter procedure, which produces parts of a low porosity maintained within reasonably close dimensional limits, combined with high mechanical strength, can be achieved. With a combination of metals, one or more may pass through a liquid phase sintering. A first pressing can be obtained at a low pressure, although work may be done at a high compacting pressure to achieve a density as high as possible right at the commencement of the operation. Although dependent on the equipment and processes developed by the particular company, it is generally found preferable to apply a relatively low pre-press pressure, and to employ a low temperature with the first sintering stage. Chemical activation can also be employed.

Powder metallurgy also provides the means of building up metal structures unobtainable by conventional techniques. Thus, unalloyable metals such as tungsten and copper can be mixed, and metals and non-metals combined to produce tailor-made structures for many different applications. A stainless sinter steel, with mechanical properties and corrosion resistance equivalent to those of the usual 18/8 stainless steel, is especially suitable for the manufacture of small components such as parts of household appliances, locks and other detail parts for motor cars and marine craft.

The unusual ability of the method to produce smooth finishes and close tolerances, in many cases without secondary machining or grinding operations, is very attractive. The damping properties of sintered parts are often better than those associated with similar parts made from wrought materials. The extra damping can in many cases compensate for the lower fatigue strength, particularly where fatigue loads are caused by random vibrations.

In powder metallurgy two new basic concepts are involved, as compared with other processes:

(a) The usable strength of a metal can be developed after its shaping operation, whereas with liquid metallurgy it is always developed before or during the shaping operation.

(b) Density is a new variable physical property, just as the amount of cold work or stress is a variable physical property in wrought metal products.

Criteria for Design

To gain the advantages of powder metallurgy in the field of complex shaped components, it is worth while remembering the following guiding principles:

(1) The average maximum surface area perpendicular to the direction of pressure should not exceed 5 sq. in., or alternatively the component should be capable of being enclosed by a 5-in.-dia. circle. The height of the product should not greatly exceed 2½ in. The ratio of diameter to height should not be more than 3:1, because the slight variation in density which occurs over the length of a component may cause a dimensional change during sintering.

(2) It is unwise for a design to call for a chamfer of less than 30° (see Fig. 4), since the tool will be prone to breakage due to the feather edge (Fig. 3), unless a suitable land (Fig. 5) can be incorporated in the component design. This land is also necessary when a convex radius is specified (see Fig. 6).

(3) Sharp edges should be avoided, and radii as generous as possible should be specified (see Fig. 7).

(4) Provided the tools have sufficient strength, parts with holes in the direction of pressing can be formed, but it is seldom practicable to core holes smaller than 0·05 in. in dia., although this is dependent on the length of the part; 0·03-in.-dia. hole in a part ¼ in. long is possible.

(5) Other design requirements which should be noted are that re-entrant angles and grooves cannot be moulded. Blind holes can be incorporated, but if the component also contains a flange then it should be at the same end of the component as the bottom of the hole (see Fig. 8). Spherical parts should incorporate a flat (see Fig. 9), to avoid the similar conditions as shown for the feather edge on the punch. Abrupt changes in cross-sectional area (see Fig. 10) must be avoided, and also thin-walled sections less than 0·05 in., since tool failure is likely to be experienced, although wall thicknesses of 0·03 in. have been achieved. The possibility of inconsistencies in densities due to insufficient powder being positioned should be borne in mind.

(6) It is generally accepted that radial tolerances in plan dimensions can be held to 0·002 in./in., whilst with an extra sizing operation this can be reduced to 0·001 in./in., or less in certain cases. Somewhat wider limits are required in the direction of pressing, 0·005 in./in. being a reasonable limit for lengths of cylindrical parts, and 0·003 in. total on washers and plates.

The cost of sintered products depends on the complexity, the properties required, the limits to be held, the number of produced pieces, and on the required production equipment. Production economy depends on the complexity of the tools and rate of production, but it can be assumed that orders for 10,000 parts or more will generally justify any kind of tools, although certain components can be justified for very low numbers required. The loss of material by the classical methods of fabrication, e.g., turning, etc., is in some cases up to 60 per cent and generally about 30 per

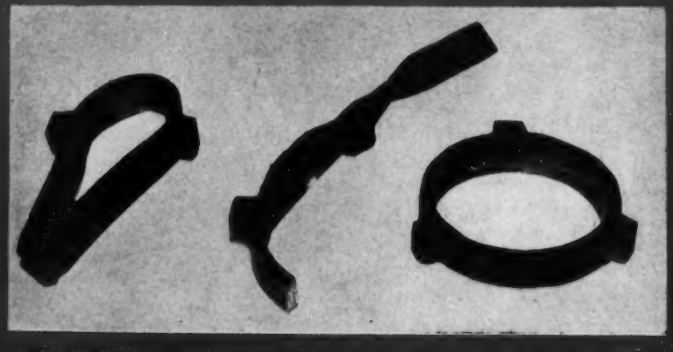


Fig. 1. Deformed component illustrating the ductility of sintered parts.

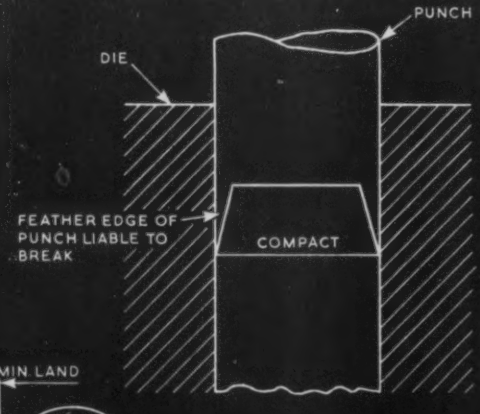


Fig. 3. Indicating a feather edge.

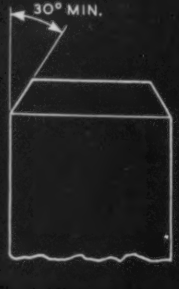


Fig. 4. Minimum chamfer.

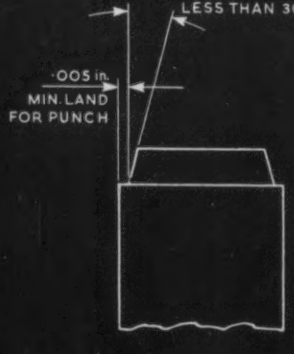


Fig. 5. Minimum land.

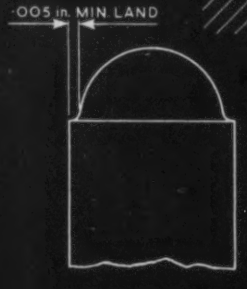


Fig. 6. Showing the land necessary when used with radiused ends.

cent, while there is practically no material loss in the case of powder metallurgy, although the initial powders are always higher in cost than wrought materials.

Tool life is dependent in some small degree on the shape of the part, powder hardness and compacting pressure, but a generally accepted and conservative figure is 100,000 parts before renewal of dies made from tool steel is necessary. Using carbide tools, the figure may be as high as 2,500,000. It is worth noting that tool life is improved if long runs of parts can be carried out without the necessity of removing the tools from the press.

The cost of dies and tools is again dependent on the complexity and size of the part, but an average figure (for tool steel) of between £100 and £250 may be considered, although for some parts the cost may be as low as £30, or high enough to run into four figures. Carbide tools are likely to be three times the cost of those made from steel.

In order to design parts specifically for production by powder metallurgy, it should be understood that although the powder is poured into a mould, it does not flow as liquid and does not behave hydrostatically under pressure. All sections need pressing to a uniform density, so that the die fill must be proportional to the thickness. There is considerable loss of pressure due to the powder particles rubbing on the die wall and on each other, making it essential to apply the compacting pressure from both ends except in very thin sections. It should be remembered too that the part has to be pushed out of the die.

When the height of the pressing is larger than the greatest cross-section dimension, the powder, when compressed, reaches a higher density at the faces where the pressure is applied than in the middle of the pressing, where the density is lower. The same effect shows up on a smaller scale for pressings of less height. With pressings of large ratios of height to cross-section, it can happen that the powder in the middle is not compressed, and the pressing or compact is not self-supporting. Not only is the height important, but also the shape, for not every shape can be utilised for pressing.

It is fairly obvious that the shape of sinterings is limited to items which can be pressed and ejected from a die, while the size is limited to the tonnage capacity and stroke of the press. Most parts produced by powder metallurgy probably do not weigh more than a few ounces each, although components weighing as much as 2,500 lb. have been produced on occasion.

Since the filling of the die is controlled by volume, any variation of flow characteristics of the powder affects the uniformity of the pressed compacts. It is necessary to fill the die with an exact volume of powder, approximately three times that of the desired compact. During pressing there is little or no flow such as with plastics, and this makes it impossible to produce shapes having re-entrant angles or holes at right angles to the direction of pressing.

Porosity

Porosity present as a controlled and orderly structure is of the greatest value in many sintered parts. Frequently the lower density permits a reduction in weight, which is valuable where inertia and momentum are important. Pore size and permeability can be altered by controlling such factors as particle size distribution in the metal powder, compacting pressure and sintering conditions. Particles must be of irregular shape in order to interlock, thus giving good mechanical properties, but where powder metallurgy techniques are used in the manufacture of metal filters, spherical particles can be used.

Sintering is done in a reducing atmosphere of hydrogen or dissociated ammonia (75 per cent H and 25 per cent N), and consists of processes which should be considered separately, as they each can influence the properties of the product. They are: (1) reduction of particle skin oxides; (2) surface decarburation where the powders are carbides (although this can be eliminated by correct adjustment of the furnace gas); (3) cementation-surface carburation, when metal powders are used; (4) cohesion of the particles associated with change in dimensions, to form a single unit; and (5) modification of the pore structure of the compact.

Although these have long been employed, the use of endothermic and exothermic gases, town gas and propane is growing in importance as a means of reducing costs of sintered components.

Vacuum sintering has been receiving increasing attention, not only in relation to metals which demand a vacuum by virtue of their composition, but also for certain carbides and engineering alloys which in the past have been sintered in a controlled atmosphere. It is claimed that vacuum sintering in certain cases yields a product having improved mechanical properties, as regards both strength and ductility. Obviously, the process is limited to those metals and alloys which have an insignificant vapour pressure at the sintering temperatures involved.

If the porosity in a sintered part exceeds 10 per cent, that is one-tenth of the solid volume per unit volume, the pores generally intercommunicate and liquids can be absorbed by capillary action. This is an essential feature of self-lubricating parts.

High-density sintered steel parts are generally understood

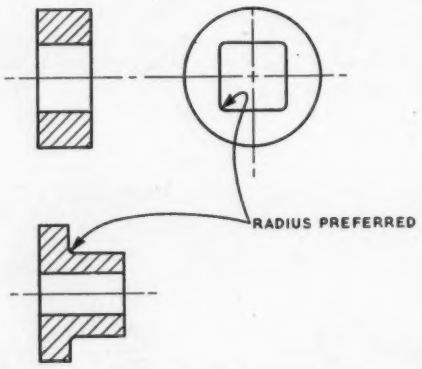


Fig. 7. Radiused corners are preferable to those with sharp edges.

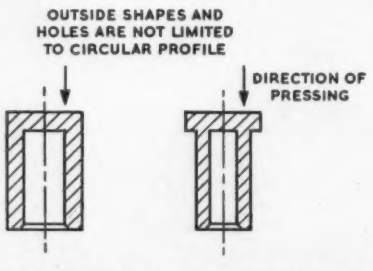


Fig. 8. Showing blind holes in sintered component.

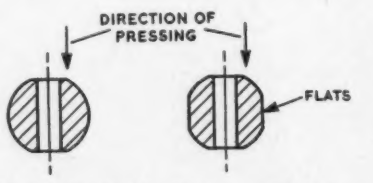


Fig. 9. Indicating the flats on a spherical part.

to be components with a total porosity of below 10 per cent. Using normal techniques of pressing at room temperature and sintering, completely pore-free sintered parts cannot be produced, even when the stages are repeated. Practical experience has shown, however, that for most applications a completely pore-free sintered part is not necessary. Where a pressure-tight component is required, various impregnation techniques can be applied in order to seal the pores.

An advantage of powder metallurgy is that improved properties or special characteristics may be obtained by filling a porous skeleton with another metal of lower melting point. An example of this infiltration technique is the absorption of molten copper under a reducing atmosphere into an iron matrix, which improves galling characteristics and electrical properties. Other materials may be similarly used, including plastics, which in the main confer a reduction in the coefficient of friction, and are therefore useful for bearings.

When considering the type of powder, it is obviously more economical to use an expensive one, if by so doing the processing is cheaper and simpler, or if the quality characteristics of the finished parts are correspondingly improved. In practice, however, a balance is maintained between the quality of the powder and the processes employed.

The substitution of a corrosion-resistant powder for a metal which would have to be plated is often a satisfactory solution. Iron compacts can also be carburised to produce materials which respond to heat treatment. In porous material, carbon is picked up more quickly than with solid materials, and carburising times are thus reduced. Similarly, cyanide hardening, Parkerising, chemical blackening and similar treatments are equally applicable to all ferrous parts. All iron parts having considerable porosity can be treated with superheated steam to provide a corrosion-resistant finish.

Recent Developments

A more recent development is the chromising of powder metallurgy parts, giving a coating which is strong, adherent and cheap.

To overcome the necessity of using a controlled atmosphere or a vacuum furnace for sintering, the technique of sintering under molten glass is of interest. Successful experiments have been carried out leading to the possibility of a series of new glass-metal alloys with interesting properties.

Continued technical progress is impossible without the creation of new materials having a high mechanical strength combined with low weight, resistance to high temperatures, resistance against corrosion and wear, special magnetic and electrical characteristics and self-lubricating or anti-friction properties.

A new low-cost approach is being made to titanium components by the powder metallurgy technique. An American company claims that valve parts (see Fig. 12) made by this method are competitive with those made in stainless steel by alternative methods. Apart from the valve seats, machining can be eliminated. Close tolerances can be maintained, and various shapes are possible up to 35 sq. in. in cross-section.

Refractory metals such as beryllium, molybdenum and tantalum can be successfully shaped by powder metallurgy methods, whereas such a result would be almost impossible by casting or hot working. One far-reaching achievement has been the production of large magnesium ingots designed for further processing such as rolling and extrusion. The objective in many instances is the production of alloys capable of operating at the elevated temperatures caused by supersonic flight. The production of continuous strip from powder is novel; copper has been used in this process, also nickel sheet and strip, Sherritt Gordon Mines Ltd. having laid down expensive plant for the latter, thus proving that strip or sheet can be rolled directly from powder.

Few realise that powder metallurgy produces some of the strongest metals known; for example, tungsten wire is made by this process, and has tensile strengths in the order of 500,000 p.s.i. It is also interesting to note the development of an aluminium known as S.A.P. by powder metallurgy, the sheet material having better physical properties at elevated temperatures than similar products of liquid metallurgy.

A good deal of work has been done towards the application of sintered aluminium powder products, and attempts have been made to produce completely finished products of the material, in some cases with ceramic additions. The application of S.A.P. inserts in thermally stressed regions of aluminium alloy components is particularly promising, because of the similarity in the coefficients of thermal expansion.

The production of ultrafine metallic powders with a particle size in the order of 300 Ångstrom units is likely to improve the products of powder metallurgy, as well as finding use in propellant formulations, catalysts and organometallic reactions. With this size of particle, homogeneous mixtures of alloy elements should be possible, and new properties might be obtained by mixing powders in proportions not ordinarily found in alloys. Dispersion hardening possibilities also exist.

A further aspect of powder metallurgy is the development

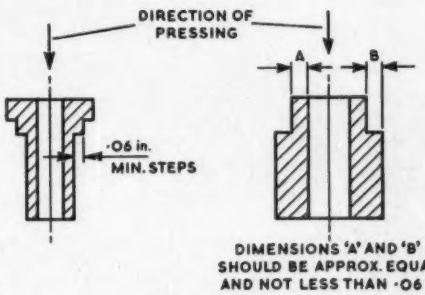
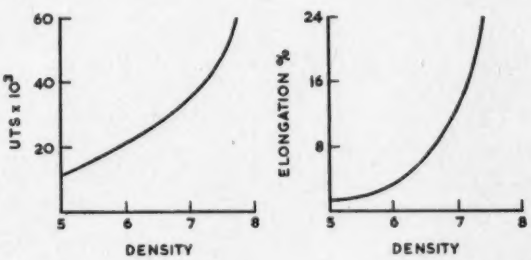


Fig. 10. Avoiding abrupt changes in cross-sectional area.



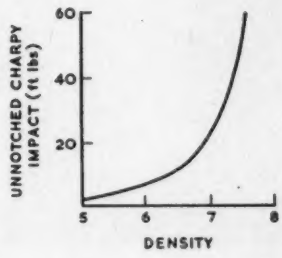


Fig. 11. Typical relationships for electrolytic iron.

of composite powders consisting of metallic or non-metallic core particles clad with nickel or cobalt. The development of this process has been carried out by the laboratories of Sherrit Gordon Mines Ltd., in Canada, and iron, aluminium, copper, chromium and silver powders have been successfully coated with nickel or cobalt. Tungsten, titanium and molybdenum are being currently studied. A wide range of oxide, carbide and boride cores can also be coated with nickel and cobalt.

Aluminium Powder Impact Extrusion

A recent development by the Aluminium Company of America has made possible precision aluminium parts for high-temperature service, by means of a powder metallurgy impact extrusion process. One prototype fabricated by the new process is reported to be unique, in that it is impossible to manufacture by any other metal-working method. It is a small ¼-in.-dia. finned tube, impacted in lengths up to 14 ft., with wall thickness tolerances in the 0·003-in. range.

The new method employs powder metallurgy techniques of compacting and sintering to form an extrusion billet of the S.A.P. type, from which rod is extruded. This rod is then cut to form slugs from which the final form is impacted. The result is a higher operating temperature limit for high strength parts fabricated from these slugs. The close-tolerance precision of the impact can now be incorporated into parts for high-temperature service, particularly in the atomic energy, aircraft and missile fields, where there is need for precision components that can retain strength and corrosion-resistance properties at elevated temperatures.

In theory, any part that may be impacted may be fabricated from this type of slug, and normal maximum and minimum size limits for impacts apply to the new process, the tolerances of the parts made being well within the close normal impact ranges. Parts have in fact been fabricated within tolerances of 0·0025 in.

Slip Casting

Investigations show that slip casting as a method for the fabrication of shaped parts is applicable not only to oxides and other ceramic powders, but also to powders of a purely metallic nature. These powder particles must be suspended in a liquid, and the slip so formed poured into a plaster mould, through which the liquid penetrates. The semi-dried slip which results assumes the shape of the mould and can be removed and sintered.

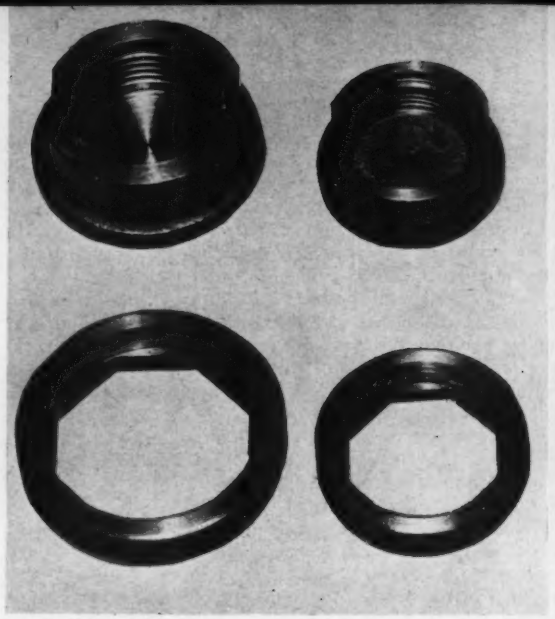


Fig. 12. Titanium valve seats (Clevite Research Centre).

Slip casting has the advantage that no pressure is applied to the mass of powder, and larger and more complicated shapes with undercuts can be formed. It is unlikely that slip casting will replace conventional powder metallurgy methods, but it will add to the applications of metal powders as a raw material for the manufacture of parts which cannot be made by conventional powder metallurgy methods.

Slip casting has the advantage that it eliminates all pressing variables, but it does introduce new variables such as: (a) liquid/metal powder ratio; (b) viscosity of the slip; (c) pH factor; (d) deflocculant binder; and (e) drying temperature and time.

From experiments, it has been determined that slip cast-

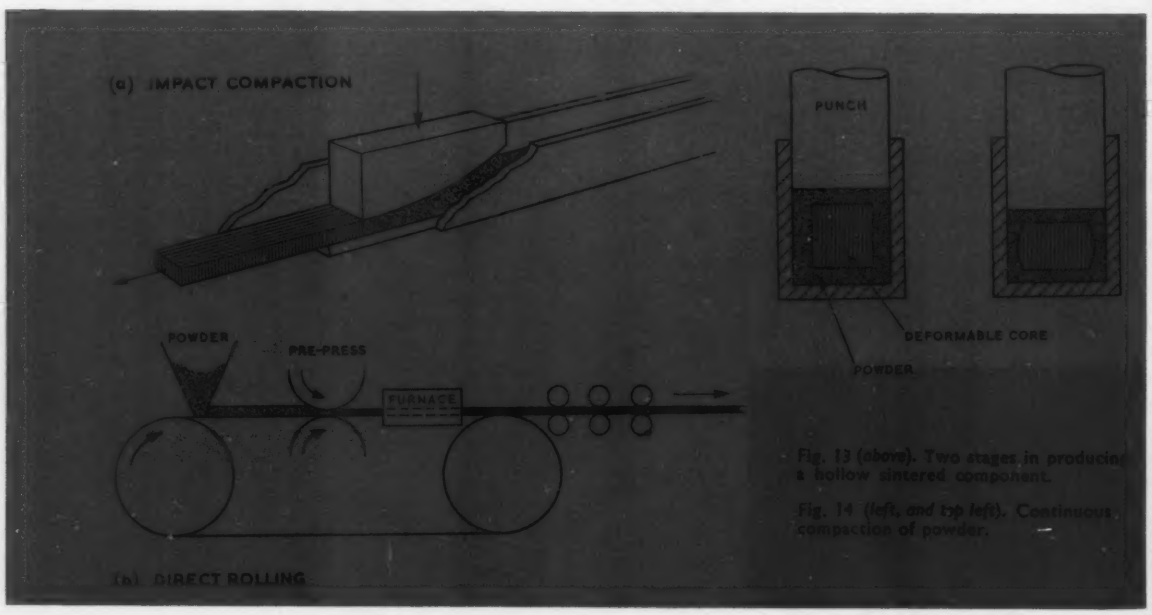


Fig. 13 (above). Two stages in producing a hollow sintered component.

Fig. 14 (left, and top left). Continuous compaction of powder.

Fig. 15. Finned tube produced by impact extrusion from aluminium powder (Aluminium Co. of America).

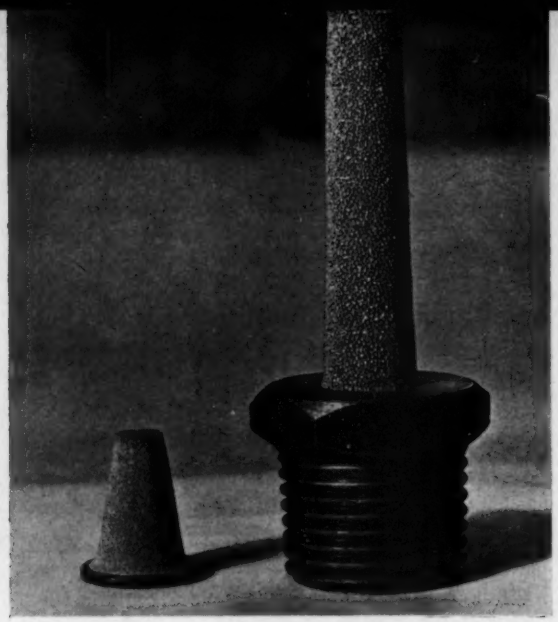


Fig. 16. Integral assembly of a filter element, with base ring (*left*) and base plug (*right*) (Sintered Products Ltd.).

ings can be made with a green strength sufficient to permit handling, and that with stainless-steel powders a density of 7·4 gm./cc. can be reached, which corresponds to that of a conventionally compacted part pressed at 50 t.s.i.

Loose Sintering

It has been reported that a pressureless sintering process can produce parts in beryllium with densities of 95-98 per cent, from powder with a particle size of about 35 microns. The moulds are filled simply by feeding in the powder to a bulk density of 45-50 per cent, sintering being carried out in a vacuum furnace. This process can be applied also to carbides, but not to iron or bronze powders.

Control of sintered dimensions appears reasonably good, although even under the best conditions the process could not be expected to compete with the high degree of dimension control obtained by conventional consolidation techniques.

High Cyclic Rate Impact Compaction

This method is without commercial precedent in the powder metal field, but has been used for the compaction of very dense refractory ceramic shapes. The compaction of the metal powders is produced by a series of impacts which are made to occur at a high cyclic rate, the high frequency of the impacts producing two effects—one a vibratory effect, and the other a forging effect. The vibratory action improves the flow of the metal powder to all parts of the die, and hastens the expulsion of entrained air. The forging effect is brought about by the high energy impacts, which densify the powders into a homogeneous mass and produce a high-density green compact.

The improvement in flow resulting from this method holds forth the prospect of producing parts with more intricate shapes and with larger cross-sectional areas than are possible by conventional means. In the impact compaction process the blows are delivered in rapid succession (1,000-2,000 blows/ min.), and, in consequence, the entrained air is effectively driven out of the powder.

Shapes difficult to make by conventional pressing, such as those with undercuts, re-entrant angles and threads, may be formed by the new process because of the improved flowability and uniform pressure distribution. Current powder metal practice depends on the ability of the powder to flow, as well as upon the response to sintering. By means of the high cyclic rate impact compaction process, flowability within the die and compaction ratio factors can become less important, although the double press and sinter technique will give similar results.

A recently patented method of powder compaction, particularly suitable for titanium, is one where a cord of explosive is wound, or a number of detonating charges are placed around, the outside of a container suspended in a tank of water. By extracting the air in the container or allowing it to escape immediately after detonation, the powder inside the container is compacted into a coherent mass by the exploding charge.

Continuous Compaction

Direct rolling of powders is the only important method being exploited at the present time for the continuous formation of solid materials (100 per cent density) from powders. The new method of continuous compaction is one where the powder is fed into a channel of width equal to the width of the required bar. A tapered (or stepped) punch of the same width compresses the powder, which is restrained from flowing forward in the channel by a movable block. Bars from 0·005-1·0 in. thick have been made by this process, and 90 per cent density has been achieved with a copper powder.

Hollow Parts with Sintered Metal Powders

The problem of producing hollow parts by powder metallurgy has so far been solved by leaving a rigid core in the pressed product. When producing self-lubricating bearings, for instance, iron sponge cores have been successfully employed.

Parts manufactured by this process have one drawback, however, which is generally common to all parts of complex shape made from metal powders—the walls which are parallel to the direction of pressing are less compact than those perpendicular to this direction. In order to eliminate this drawback, successful tests have been performed with deformable cores at the Institute of Technology of the Naples University (Italy); a metal which melts and deforms easily, like lead, is being used. During the preliminary pressing of the metal powder in the mould the lead core expands laterally, producing a strong pressure in that direction. Shape and dimensions of the cavity cannot be strictly fixed, as with iron sponge, but this drawback is offset by better

mechanical characteristics in the walls parallel to the direction of pressing.

If it is desired to make a small hollow cylinder, a cylindrical mould is used, with a diameter equal to the external diameter of the small cylinder to be produced (see Fig. 13). Enough powder is introduced to make the underside half of the cylinder; the lead core is placed upon this, further powder being added for the walls and the top portion, and pressing is performed in the usual way. Under the pressure the powder compresses the lead core over its entire surface, but with varying intensity, the pressure being greater on the bases than on the lateral surfaces. The lead core is deformed as shown in Fig. 13 and exerts a strong lateral pressure on the cylinder walls. The result is a highly compact product, with increased density and better mechanical characteristics than those of samples made with the usual pressing methods. The method lends itself to various applications, and in certain cases the cavities and internal ribbing of the samples are obtained by using turned cores, the molten lead escaping through a small vent during the sintering operation. Production of thin-walled parts (less than 1 mm.) with excellent properties is reported to be possible.

Manufacturers

So far this article has dealt only with the basic principles of the process, and in some detail with the designer's aspect, and it would not be complete without some reference to the different materials and combinations which are commercially available. The choice of material is governed by considerations such as cost, loading and the general design concepts, and the designer would do well to contact a manufacturer at an early stage in the design.

In addition to components made by powder metallurgy techniques, other fields are being continually expanded to utilise the sintering process. One such application is in plastics impregnated metals, where sintered metal is used as a base, and another the manufacture of sintered plastics components. A well-established use is in the production of metallic filters and friction linings. These latter require separate treatment, and for this reason such manufacturers have not been included in the following table.

The following list gives some of the principal manufacturers of metal powders and sintered components.

Company	Remarks
Bound Brook Bearings Ltd.	Oil-retaining bearings and components.
Basildon Metal Powder Parts Ltd.	Components.
Borax Consolidated Ltd.	Metallic borides.
Daniel Doncaster & Sons Ltd.	Components.
G.E.C. Ltd. (Osram Metals Division).	Heavy alloys, sheet, wire, strip, etc.
Hard Metal Tools Ltd.	Metallic carbides for tools.
High Speed Steel Alloys Ltd.	Metallic carbide powders for tools.
Firth Brown Tools Ltd.	Metallic carbide powders for tools.
McKechnie Brothers Ltd.	Copper powders.
Murex Ltd. (Powder Metallurgy Division).	Magnetic materials, sheet, wire, strip, etc.
Metal & Plastic Components Ltd.	Sintered steels.
Morgan Crucible Co. Ltd.	Oil-retaining bearings.
Mond Nickel Co. Ltd.	Nickel powders.
Manganese Bronze & Brass Co. Ltd.	Oil-retaining bearings and components.
J. & J. Makin (Metals) Ltd.	Powders of all types.
Powder Metallurgy Ltd.	Powders of all types.
J. Rigby & Sons Ltd.	Components.
Sintered Metal Components (Chard) Ltd.	Components.
Sintered Products Ltd.	Components.
Telcon Metals Ltd.	Magnetic materials, sheet, strip, wire, etc.

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"Impact Extrusion Slugs", Aluminium Co. of America.

NIOBIUM ALLOYS

THE need for an alternate cladding material capable of withstanding the high operating temperatures (650 to 800 deg. C.) of advanced designs of reactors has motivated a consideration of alloys of the refractory elements. The formation of the iron-uranium eutectic at 730 deg. C. precludes employment of the Type 347 (Cr, Ni plus Nb) stainless steel cladding. The development of niobium alloys appears attractive because niobium, which is already adequate in mechanical strength, thermal conductivity and corrosion resistance, can be improved markedly by alloying. An investigation* was recently undertaken at the Battelle Memorial Institute to develop a niobium-base alloy which would be superior in strength to stainless steel at 650 to 820 deg. C., resistant to attack by sodium at 820 deg. C., and capable of being fabricated by standard techniques, in which ductile welds could be produced.

Selection of alloying elements was based on their probable strengthening effect, or on their ability to improve fabrication properties. Chromium, molybdenum and zirconium were used as binary additions, and aluminium, chromium, tantalum and titanium were used for ternary alloys. Except for titanium, all of these elements should strengthen niobium by solid-solution or age-hardening mechanisms. Titanium additions tend to improve the formability of alloys containing aluminium, chromium and tantalum.

Considerable attention was paid to ensuring that promising alloys could be readily fabricated. Two series of alloys were prepared to study this problem, in particular the initial breakdown of the cast structure. In the evaluation, elevated-temperature short-time tensile tests on sheet specimens were carried out to obtain strength data, while tension, shear and bend tests were employed to study the weldability of the alloys. Both spot and arc welding were investigated.

As a result of the research, it can be concluded generally that niobium-base alloys can be developed which exhibit very interesting properties at 650 to 800 deg. C. In addition, the technology of niobium has been advanced by the development of techniques which allow niobium-base alloys to be fabricated at relatively low temperatures and consequently without the need for protection against oxidation during fabrication.

Of the alloys studied, the 3·21 per cent Cr alloy exhibited the best strength properties at 650 deg. C. (0·2 per cent offset yield strength of about 120,000 p.s.i.). In general, however, very large increases in strength at elevated temperature were obtained by the addition of moderate amounts of chromium and zirconium. Although all the alloys could be fabricated, the niobium-zirconium alloys appeared to possess the best characteristics, and no difficulties in producing ductile welds are expected in any of the alloys studied.

The niobium alloys studied can be cold-rolled with ease once the as-cast structure has been broken down.

* *Development of High-strength Niobium Alloys for Elevated-temperature Applications* (*BMI*-1417).

USE OF INTERPOLATION FORMULAE

by A. ORMEROD, B.Sc., D.I.C., A.M.I.Mech.E.*

IF a compression member can carry a maximum axial load P_y when no bending moment is applied, and can withstand a maximum bending moment M_y when there is no axial load, the question often arises: What combination of bending moment M and axial load P may be safely applied to the member? If no other data are available, an empirical formula may be used; the limit of safe loading is considered to be reached when

$$\frac{M}{M_y} + \frac{P}{P_y} = 1.$$

A formula of this kind is often referred to as an "interpolation" formula, since it is obviously correct for the extreme values—$M = M_y$, $P = 0$: and $P = P_y$, $M = 0$—but there may be some doubt about its accuracy for intermediate values.

Interpolation formulæ are used in so many fields, and are so convenient, that it is both interesting and constructive to examine a few specific cases and to form some idea of the accuracy to be expected.

Combined Bending and Direct Stress

ELASTIC DESIGN—Considering first a member subjected to both bending and direct stress as instances above, and supposing it to be so short that no question of elastic instability arises, the greatest permissible bending moment $M_y = f_y Z$, and the greatest permissible axial load $P_y = f_y A$, where f_y is the yield stress. If M and P are applied together, the material will yield if

$$\frac{M}{Z} + \frac{P}{A} = f_y, \text{ which may be written } \frac{M}{M_y} + \frac{P}{P_y} = 1.$$

In this case the interpolation formula represents accurately the design conditions, it being understood, of course, that an appropriate safety factor is used. The formula may be represented graphically as shown in Fig. 1, any loading which falls within the shaded area being safe.

LIMIT DESIGN—If design is based on the full resistance developed by the member, the greatest permissible axial load P_L is equal to $f_y A$ as before. The limiting stress distribution assumed for bending, however, is as shown in Fig. 2(b). The moment of resistance depends, of course, on the shape of the cross-section. Considering for simplicity the simple rectangular section shown in Fig. 2(a), the limiting moment of resistance M_L is equal to $\frac{1}{4} f_y BD^2$. The stress distribution assumed for combined bending and direct load is shown in Fig. 2(c). The central part of the bar resists the direct load, the outer parts the bending.

The effects of the two types of loading are not simply additive; in fact, the situation is more favourable than that; the central part of the bar, which is less effective in resisting bending, can resist the direct load with full efficiency.

The resistance to direct load is seen from Fig. 2 to be $f_y Bx$, whilst the resistance to bending is $\frac{1}{4} f_y B(D^2 - x^2)$, which leads to the relation

$$\frac{M}{M_L} + \left(\frac{P}{P_L}\right)^2 = 1.$$

This is shown plotted in Fig. 2(d), the shaded area representing safe loading.

It may be useful to restrict the term "interpolation" formula to linear equations, and to refer to non-linear equations as "interaction" formulæ. It will be noticed that if the linear formula is used in this case, the resulting design is conservative.

Compound Stress

When a material is subjected to bi-axial stress, safe loading must be estimated by applying a criterion of failure appropriate to the stress system and to the material.

TENSILE STRESSES—If both stresses are tensile, it may be thought there is a possibility of brittle fracture, and that the maximum principal stress criterion is appropriate. This criterion is very simple: neither of the stresses must exceed the stress f_T which causes failure in simple tension. This will be the fracture stress for a material such as cast iron, which is brittle in simple tension, or the yield stress for a material that is ductile in simple tension. The rule is shown graphically in Fig. 3(a), and is seen to be a wide departure from the linear interpolation formula.

TENSILE AND COMPRESSIVE STRESSES—This combination of stress applied to a ductile material may be expected to lead to failure by yielding, and the maximum shear stress criterion may be adopted. Yield is expected when the maximum shear stress $\frac{1}{2}(p_1 + p_2)$ is equal to the maximum shear stress obtaining when the material yields in a simple tension test, i.e., $\frac{1}{2} f_y$. This gives the simple interpolation formula

$$\frac{p_1}{f_y} + \frac{p_2}{f_y} = 1, \text{ as indicated in Fig. 3(b).}$$

An alternative criterion, the Mises-Hencky criterion, states that yield will occur when $p_1^2 + p_2^2 + p_1 p_2 = f_y^2$. The relation is shown in Fig. 3(c); it is seen to be rather less conservative than the maximum shear stress criterion.

Combined Bending and Torsion

BRITTLE MATERIAL—When a circular shaft of brittle material, tensile strength f_T, is subjected to combined bend-

* Royal Military College of Science, Shrivenham.

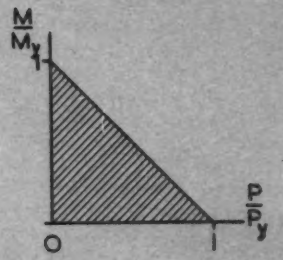
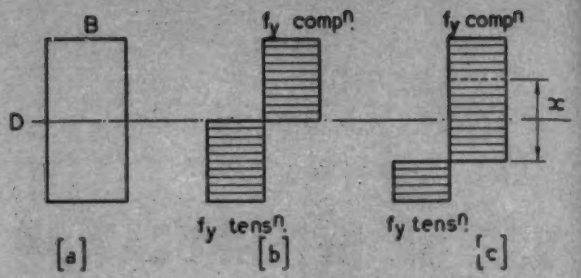
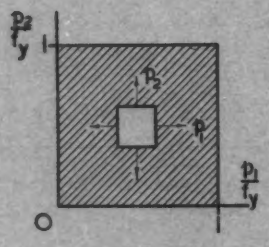


Fig. 1





[a]
Max Principal Stress Criterion

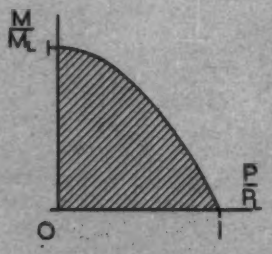
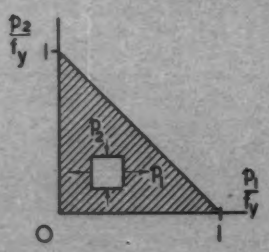
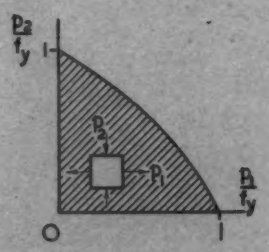


Fig. 2 Bending and Direct Stress. Limit Desig



[b]
Max Shear Stress Criterion



[c]
Mises Hencky Criterion

Fig. 3 Compound Stress

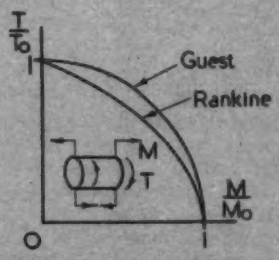


Fig. 4 Combined Bending and Torsion

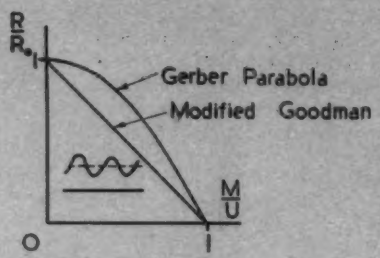
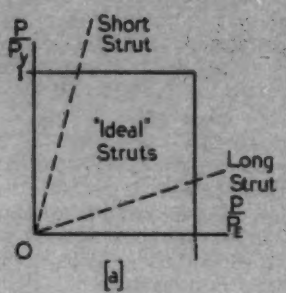
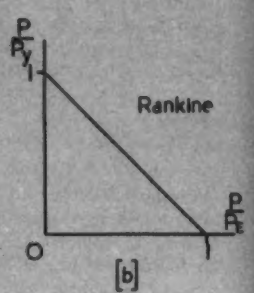


Fig. 5. Fatigue





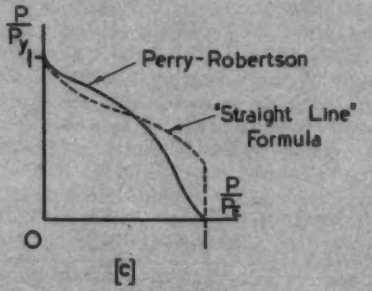


Fig. 6. Struts

ing and torsion, the maximum principal stress criterion is appropriate. The shaft, when subjected to a bending moment M_o alone, fails when $M_o = f_T I/r$. Since according to the criterion the material fails in shear when the shear stress is numerically equal to f_T, the shaft, when subjected to a torsion T_o acting alone, will fail when $T_o = f_T J/r = 2M_o$. The criterion of failure when M and T are applied together is usually expressed as the "Rankine formula",

$$M_o = \tfrac{1}{2}\left[M + \sqrt{M^2 + T^2}\right],$$

which reduces to the interaction formula

$$\left(\frac{T}{T_o}\right)^2 + \frac{M}{M_o} = 1.$$

This is shown in Fig. 4.

DUCTILE MATERIAL—If the maximum shear stress criterion is used, it follows that the yield stress in shear is one-half the yield stress in tension, i.e., $q_y = \frac{1}{2}f_y$ and $T_o = M_o$.

The rule for combined bending and torsion is usually expressed as the "Guest" formula,

$$T_o = \sqrt{M^2 + T^2}.$$

This reduces to the interaction formula

$$\left(\frac{T}{T_o}\right)^2 + \left(\frac{M}{M_o}\right)^2 = 1,$$

which gives the circular plot shown in Fig. 4.

If the Mises-Hencky criterion is used, q_y is taken as $f_y/\sqrt{3}$, $T_o = 2M_o/\sqrt{3}$, and the interaction formula is again

$$\left(\frac{T}{T_o}\right)^2 + \left(\frac{M}{M_o}\right)^2 = 1.$$

Struts

IDEAL STRUTS—Whereas a short compression member fails by yielding when the axial load P reaches the value $P_y = f_y A$, i.e., when the member reaches the limit of its elastic strength, a longer member buckles when the load P is equal to the critical or "Euler" load for elastic instability, i.e., when the member reaches the limit of its stiffness. The buckling induces bending stress, and this, combined with the direct compressive stress, leads to yield and complete failure. The value of P_E, with the usual notation, is $\pi^2 EA/\left(\frac{1}{k}\right)^2$. The behaviour of the ideal strut can be represented graphically as shown in Fig 6(a). Any particular strut is defined by its ratio P_E/P_y, i.e., $\pi^2 E/f_y\left(\frac{1}{k}\right)^2$. A line drawn on the diagram with this slope cuts the interaction curve at a point which indicates the failing load for the strut in question.

ACTUAL STRUTS—In practice there are inevitable inaccuracies of manufacture and assembly, so that real struts are not perfectly straight before loading and the load is applied with some slight eccentricity. These two factors cause bending stress, and yield occurs at a load less than either P_y or P_E. Various formulæ have come into use to express the failing load of an actual strut; the formulæ are based ultimately on test results, although some of them incorporate an estimate of the probable fabrication errors. These formulæ can be put into the interaction form, and it is of interest to examine them in this light.

A very early suggestion, the classical Rankine formula, has the simple linear interpolation form

$$\frac{P}{P_y} + \frac{P}{P_E} = 1.$$

The line is shown on Fig. 6(b). On Fig. 6(c), for comparison, examples are shown of formulæ in current use, a "straight line" formula $P/A = f_y - c(l/k)$ and a Perry-Robertson formula. It will be seen that over most of the range of struts the Rankine formula is more conservative than the alternatives.

Fatigue

In situations where fatigue is the governing factor, loading often consists of a mean or steady load, to which is added a fluctuating load. The basic information required for any particular steel is the safe range of fluctuating load for any given mean load. To make a series of tests using different ranges at several mean loads involves a great deal of work and expensive equipment. Tests at zero mean load are comparatively simple, and it is a great convenience to use the results of such tests with some formula of interaction.

The two points at the extremes are fixed, i.e., the safe range R_o at zero mean load as determined by testing is at one extreme, and at the other extreme the ultimate strength U is taken as the mean load at which the permissible range R is zero. The issue to be decided is the course the interaction curve takes between these two extremes. An early suggestion based on the data available at the time was the "Gerber parabola"

$$\frac{R}{R_o} + \left(\frac{M}{U}\right)^2 = 1,$$

where M is the mean stress. An alternative suggestion made in the light of later results was the "modified Goodman straight line"

$$\frac{R}{R_o} + \frac{M}{U} = 1.$$

The two formulæ are shown graphically in Fig. 5.

More Complex Interactions

From the examples quoted it will be seen that an interaction formula can be used in situations where two factors are involved. In many design problems, of course, there are more than two main factors to be considered. Where an exact solution would call for intricate analysis, a practical approach to a solution may be made by breaking the problem down into simpler elements.

An example lending itself to this procedure is a beam with an axial load. With the axial load acting alone the beam is a strut, and the greatest permissible load P_o can be determined from a strut formula. The bending moment acting alone will give rise to bending stresses which will be increased by the tendency towards lateral instability. Interaction formulæ for bending, similar to the strut formulæ, have been developed, and one of these may be used to determine the greatest permissible bending moment M_o.

The final step in the solution is to use a third interaction formula to determine what combinations of axial load P and bending moment M are safe. In the absence of any other data, a straight-line interpolation formula may be used, i.e.

$$\frac{M}{M_o} + \frac{P}{P_o} = 1.$$

This is the method adopted in BS 449:1959, "The Use of Structural Steel in Buildings".

Conclusion

The examples considered illustrate the use of interaction formulæ, although they give only a slight indication of the very wide field of application. In almost all the instances studied, a linear interpolation formula offers a conservative estimate for design use, although it would be unwise to extend this generalisation to other fields without further investigation.

INFORMATION FOR ENGINEERS

So much technical information is published that a busy technologist cannot afford the time to keep up with it. The author maintains that much useful assistance in scanning the literature is readily available, and that most of the effort needed to keep up can be delegated. Suggestions are made for a practical system

by F. MACHON *

ARE you content with the assistance you get from the technical literature? When this question was put to technologists during an inquiry made for D.S.I.R., over 70 per cent of the answers were in the affirmative. Do you in fact get good assistance from other people's published work? A report on the inquiry† finds that only a small proportion of technologists do, or even have the habit of referring to the literature for help.

The plans announced for the National Lending Library for Science and Technology, and recent reports of the enormous effort being devoted to technical information in Russia, make this a suitable time to consider what technical information services are at present available to engineers.

It seems likely that, although a minority of engineers are worried about their communications, there are a great many more who are not, but should be. Whether one is at present satisfied or not, therefore, it is worth checking up from time to time that one knows what services are currently available, and how much effort and cost are required to get them used.

The Information Required

All engineers and other technologists do, in fact, rely upon good communications with some other part of the profession and those who serve it. The information they need, whether technical or commercial, might be classified as follows:

News—whether of ideas, activities or products.

Data—positive answers to direct questions.

Background—the state of the art on a topic that one has not previously studied.

However little effort may be given to obtaining such information, the yield will be greatest if the work is planned and delegated to specialists as far as possible. The following is intended to help in such planning by describing the types of sources that should be considered, and the kind of organisations that work in practice.

* *Technical information engineer, Research Laboratories, D. Napier & Son Ltd.*

† *"What They Read and Why", by Nigel Calder, D.S.I.R.—2s.*

Getting the News

Most technical reading, it appears, is done in order to keep up with the latest developments. The primary source of technical news is certainly the specialist periodical; the editorial staff are very well placed and qualified to maintain a running assessment of trends in their specialised field. Many technologists, however, have general interest in a number of fields, and at the same time are concerned with every detail in several particular techniques or studies. The number of relevant periodicals may then be inconveniently large, while none may offer all the detailed coverage required.

The only way for a busy man to scan dozens of periodicals is to have himself provided with a list of the titles of all the articles which have appeared recently. This may be compiled weekly in the library of the organisation or in a public reference library. It can be scanned in a few minutes, and need not be compiled by the engineer himself. The engineer can select items from the list, and there will then be a reasonable chance that most of his reading will be purposeful and useful.

The scanning of the periodical literature can be taken a stage further if the scanner reads regularly the special items giving news of products and publications which most magazines carry. It helps if these are listed, and ticked off as they are read each week or month. Examples of such regular news articles are:

"Design Literature" —*Product Engineering*

"New Books" } —*Engineering Materials and Design*
"Materials in the News" }

"Meetings and Papers" } —*Engineering*
"Publications" }

This list is quite arbitrary, of course—there are dozens. They give numerous references, from learned papers to sales brochures, which can be listed on the weekly scanning sheet.

Engineers will usually know which periodicals they wish to see or have scanned. Periodical titles are listed, however, in such references as: *Willings Press Guide, Ulrich's*

Periodicals Directory, *The World List of Scientific Periodicals*, and several others.

Other sources for the scanner might include trade periodicals and the better sort of house magazines. Such publications as the *English Electric Journal* and the *Brown Boveri Review* include technical articles of the greatest authority.

The required detail will tend to be found principally in the periodical publications of various bodies which examine the literature relating to some particular interest and publish lists of titles, sometimes with brief abstracts. These may also be scanned quite effectively by someone other than the interested engineer, so long as he is informed of the fields of interest and doesn't aim to score too high. The scanner must include doubtful references, and be prepared to put forward many more than will be selected.

Some of these Abstracts are organised by such associations, as, for instance, the *Production Engineering Research Association of Great Britain* (*P.E.R.A.*). This produces a monthly Bulletin which lists titles, suitably classified, and gives a description in a line or two. Photocopies of the articles referred to, or originals, may be obtained from the P.E.R.A. library. This Association also publishes a cover-to-cover translation of a Russian periodical, translated as the *Russian Engineering Journal*. This contains condensed versions of items selected from the Russian technical Press, and gives numerous other references to Russian technical literature.

Abstracts, reviews and digests of this sort enable a very wide field indeed to be scanned, although at secondhand. More than 1,000 trade associations are classified in the *Report on Industrial Trade Associations* published by Political and Economic Planning, and many of these publish literature abstracts which are available to non-members. Many commercial firms also publish useful information—the Mond Nickel Co., for instance.

Official sources are generous. One might mention *European Technical Digests*, published monthly and sponsored by fourteen O.E.E.C. countries. These cover about 1,000 European technical journals, and are one of a number of useful European Productivity Agency publications. There are also the periodical lists published by the Technical Information and Library Services of the Ministry of Aviation, and others from similar sources, and the weekly *The Official Journal* (*Patents*). This lists all the new patent applications and complete specifications accepted, with brief descriptions. Copies of the full specifications may, of course, be had. This journal also lists additions to the very useful Patents Office Library.

In planning one's coverage of abstracts journals, it is as well to take experienced advice if necessary. A good library will be able to refer to a suitable list, and to indicate those most likely to be useful. The Department of Scientific and Industrial Research has a technical information service, and A.S.L.I.B. exists to supply all kinds of assistance with the information, but to its members only.

In some technologies the period in which articles retain news interest may be compartively long. It is probably best, therefore, to mention under the heading of News such long-period abstracts and summaries as the six-monthly publication *British Chemical Plant*, by the British Chemical Plant Manufacturers Association, and the *Digest of Literature on Bearings, Lubricants and Lubrication*, published annually by the American Society of Mechanical Engineers in *Mechanical Engineering*, which is actually less of a digest than a review of the position.

The effort required to prepare scanning lists from so many sources is proportionately small when it can be done by a specialist serving a number of technicians. The scanner may have this as only a part of his job, at the one extreme, or may be a member of the staff of an information department at the other. In any case, specialisation is desirable because it:

(a) ensures that the scanning is done regularly;
(b) provides coverage of a far wider section of the literature than the engineer can hope to do entirely on his own; and
(c) saves a great deal of duplicated effort as compared with a system in which individuals do their own scanning.

The use of a weekly scanning list also:

(a) reduces the numbers of periodicals that must be bought; and
(b) avoids the delays which arise from circulating periodicals to long lists of people.

Where no assistance at all is available, however, the service can be obtained from one of the several professional abstracting information services. Examples of this type of concern in Great Britain are Infosearch and Silver End Documentary Publications.

Lectures, symposia, conversazione and exhibitions require little comment. One may well arrange to have forward notice of these included in the scanning list, but I am inclined to think that any kind of lecture or discussion is more valuable when one reads it afterwards.

Finding Data

A large part of getting a direct answer is in putting the correct question. For this reason, and because direct questions are often urgent, a verbal discussion with an expert who can make sure he is giving the type of answer required is undoubtedly the best. It is useful to keep a list of such expert sources as are available to telephone, and the article "Where to Find Technical Information" (*Engineering Materials and Design*, March 1960) makes a good basis for this.

For inquiries where answers would be expected to appear in some standard work of reference, the first approach should be through the library. Anyone unfamiliar with the system should not underestimate the resources of even a modest municipal reference library. Assistance in locating the correct reference will also be given by D.S.I.R. or A.S.L.I.B. (who publish their *Guide to Sources of Information in Great Britain and Northern Ireland*); or the appropriate professional or trade association may be able to save one's time by giving good advice. D.S.I.R., of course, operate a number of research survey and investigation establishments, and direct reference to these is profitable when they are actively concerned with the subject of one's inquiry.

If you work where you can easily visit a large library, you should be able to obtain answers to most data inquiries within the day, by identifying likely references and then going to the library to consult them. You will be very much quicker than this if you can persuade the holder of your reference to look it up for you, and give you your answer over the telephone.

A number of excellent data sheets are now published as continuing series by various magazines, e.g., *Engineering Materials and Design* Data Sheets, *Machinery* Data Sheets, *Product Engineering* special reports, and *Machine Design* Design Abstracts.

When more complex or unusual data are required, however, it will be necessary to turn again to lists of titles of papers and publications. The annual or cumulative indexes, such as *Engineering Index*, the *Annual Cumulation of the Monthly Lists of the U.K.A.E.A.*, the *Applied Science and Technology Index*, the *A.S.M.E. Index*, and indexes of the professional associations, will have to be scanned for titles likely to be appropriate. Such lists as the U.K.A.E.A. *List of Publications Available to the Public*, and their *Sources of Information in Atomic Energy*, and other official publications, may also be consulted. The publications of the National Bureau of Standards, U.S. Department of Com-

merce, are frequently used—their *Tables of Thermal Properties of Gases*, for instance.

Where time allows, European authorities may be consulted by means of the European Productivity Agency *Question and Answer Service*. This operates among O.E.E.C. countries through a National Information Centre in each. This system is described in detail in the O.E.E.C. publication, *International Guide to European Sources of Technical Information*.

Data often have to be manipulated to bring them into the form required for use, and the demand for a particular item is always likely to be repeated later. It is therefore desirable that information arising from such inquiries should be retained and organised, to avoid searches and subsequent manipulations being duplicated.

Collecting Background Information

The collecting of literature to provide a wider survey of some topic will not generally be as urgent as data inquiries often are, but will more frequently be required to be as complete as possible. Text-books will often play a greater part, and serious periodicals which consider the implications of technical matters, such as *The Economist*, or *The Times* newspaper, are more likely to be appropriate.

For this class of inquiry it is even more important that the searcher should be well-briefed. A great deal of effort may otherwise be wasted in selecting materials which are not relevant. A common method is that a reading list is first completed from which the interested engineer selects a first half-dozen items. He may, of course, have to compile his own list with library assistance. The first lot of books and papers are likely to contain bibliographies and references, which may be checked against the reading list, and probably some additions will be made.

In searching for this type of information a rather flexible approach may save time. When one has no previous knowledge of the field, for instance, a useful first step may be to consult any magazine articles which attempt a state-of-the-art assessment, even if this is aimed at too low a technical level. Such articles may nevertheless be authoritative, and may well help one to determine which are the names and the institutions whose work will repay early study. These articles may also give other clues, as to occasions or dates for instance, which will expedite the search.

The Essential Approach

The various authorities and sources that have been given are not intended as a complete list for any particular type of demand; they are given only as examples of the various types of assistance that are available. If they do not apply closely to your own requirements, you may be sure that a little investigation will enable you to produce an appropriate list for yourself. The important point is that the assistance one gets from the literature will depend upon the effort that can be put into getting it. There is no mystery; a large part of the effort can be made mechanical if it is planned, and a good service need not require very much of any engineer's time.

LAMINATED METAL-CERAMIC COMPOSITE MATERIALS

THE successful structural use of materials such as alloys of steel, aluminium, magnesium, titanium, etc., is made possible by the ductility which such materials possess. Without ductility, any stress-concentration (such as a hole) will cause failure at low nominal values of tensile stress. Such behaviour is characteristic of "brittle" materials. However, the common ductile metals and metal alloys become too soft, or even melt, at temperatures encountered in gas turbines, high-speed aircraft and missiles.

Many ceramic materials have remarkable high-temperature properties, and are also very strong. However, they have little or no ductility at normal (room) temperatures, i.e., they are brittle. Various methods of overcoming this deficiency have been tried, as, for example, at the University of California, Los Angeles, where a method of *prestressing*, using wires under tension, has been applied. A more direct approach is to attempt to introduce ductility into the ceramic material itself. Much work has been done on "cermets", in which ceramics and metals are mixed together, although the results have not been entirely successful. The main reason for this can be found by examining the nature of ductility itself.

It is well known that the ductility of metals results from slip of individual crystals (grains) on many closely-spaced internal planes, as a result of shearing stresses. In a brittle material, such as a ceramic, the amount of slip that occurs under the application of a shear stress is negligible at room temperature. This suggests that the combination of a ductile metal with a brittle ceramic might permit some slip, and thereby utilise the best features of both materials.

However, a direct mixture of metals and ceramics (as in cermets) does not utilise the two materials in the best possible manner. For example, if a ceramic body has many small spheroidal pieces of metal imbedded in it, any plastic deformation of these particles requires a similar plastic deformation of the ceramic, which is not possible without cracking. On the other hand, a composite material made largely from metal, in which small spheroidal particles of ceramic are imbedded, will not exhibit the desirable high-temperature properties of the ceramic; it will behave more like a metal. It therefore seemed advisable to develop, if possible, a combination of materials in which the ductile component is more efficiently utilised.

The basic features of a new approach are (a) the utilisation of closely-spaced thin planes of metal within the ceramic material, thereby providing a slip mechanism; and (b) the random arrangement of small elements of such composite material so as to provide for slip under all directions of loading (combined stresses).

To accomplish this, alternate thin layers of ceramic and metal are deposited until a laminated body is formed. This body could not be expected to have ductility in all directions. To provide random orientation, the laminated body is broken up into very small particles, but not so finely that the laminations are eliminated. These particles are then sintered under elevated temperature and high pressure to produce the desired structural shape. The result is a composite material composed of small "pseudo-crystals" in each of which there are many closely-spaced thin parallel planes of metal, these pseudo-crystals being arranged in more or less random orientation.

Although little is yet known about the actual internal behaviour of such materials under various types of loading, it is believed that the ceramic planes will slide over each other (under shear stress) by internal slippage of the thin metallic planes. Theoretically, there should be several slip systems at different orientations within each "pseudo-crystal", if continuity of the polycrystalline material is to be maintained under any type of combined loading. The presence of only one system requires that the pseudo-crystal be able to rotate slightly with respect to its neighbours. This is provided for by ensuring that the "grain boundary" is formed of a thin layer of metal, to which all the adjoining metallic planes are bonded.

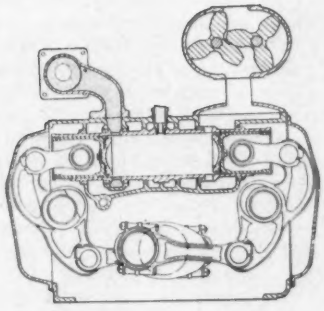
Extract from a paper by Stanley and Knapp (consultants to Rand Corp.), presented at the Sixth Sagamore Conference.

DIESEL ENGINES UP TO 300 B.H.P.: PART 3

This final section concludes the survey of diesel engines obtainable in the United Kingdom

Rootes (Tilling Stevens Ltd.)

The Rootes 3·26-litre diesel engine is a water-cooled, two-stroke, high-speed opposed piston engine having three cylinders, each cylinder containing two pistons. With slight modifications, the engine can be operated as a multi-fuel unit. The pistons in each cylinder are linked to a common crankshaft through rocker levers, the pistons also performing the function of inlet and exhaust valves. Air is supplied by a Rootes-type blower driven by a triplex chain, and the injector is at mid-length of each cylinder. The combustion space is formed by the cavities in the crowns of the opposing pistons. Maximum continuous rating is 80 b.h.p. at 1,800 r.p.m., with an overload rating (1 hr.) of 88 b.h.p. at 1,800 r.p.m. The maximum torque is 240 lb. ft. at 1,200 r.p.m., and the dry weight 997 lb.

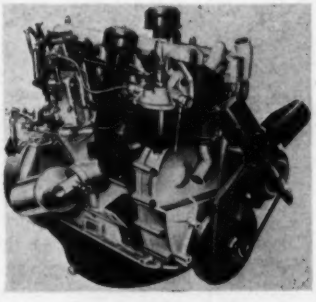


Arrangement of pistons.

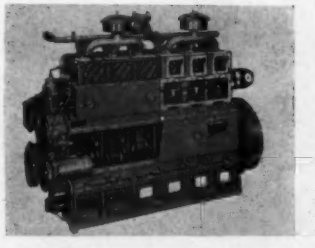
Rover Co. Ltd.

The Rover 2-litre diesel engine is a four-cylinder model using direct fuel injection, the overhead valves being operated from a roller-chain-driven camshaft. The cylinder liners are of cast iron and are of the wet type. Bore is 85·7 mm. and stroke 88·9 mm., giving a capacity of 2,052 cc. Maximum b.h.p. to automotive rating is 51·2 at 3,500 r.p.m., the maximum torque being 86 lb. ft. at 2,000 r.p.m. The detachable cast-iron cylinder head carries all the valve gear, and the overhead valves are operated by pushrods.

The engine has copper-lead main and big end bearings, roller-type tappets and tin-plated aluminium alloy pistons with a trough cast in the crowns. The fuel system is by mechanical fuel lift pump with a fuel filter, and the injection pump is the C.A.V. D.P.A. with mechanical governor. Pintaux-type injection nozzles are fitted, with glow plugs for cold starting.



Rover 2-litre.



F6 20·16-litre.

Russell Newberry & Co. Ltd.

The D and DX series of engines are vertical four-stroke high-speed power units. Overhead valves operated by pushrods are employed, and on the RD1 and DX1 models a single camshaft is fitted. On the other D and DX models separate camshafts for exhaust and inlet valves are used. Indirect injection is employed in conjunction with a swirl-type combustion chamber, and wet-type cylinder liners are fitted to all engines.

The E-type engine is a four-stroke vertical power unit with overhead valves operated by pushrods, incorporating wet-type cylinder liners. Indirect injection with a swirl chamber is employed in the combustion process. The F-type engine has a similar type of combustion system to both the D and E types; it also has overhead valve gear and renewable wet-type cylinder liners.

Basic type	No. of cylinders	Capacity (litres)	Max. continuous rating (b.h.p./r.p.m.)	Max. power (b.h.p./r.p.m.)	Dry weight (lb.)
RD1	1	1·32	11/1,250	12/1,250	784
D2	2	2·64	21½/1,200	23/1,200	1,316
DX2	2	2·64	24/1,500	26/1,500	1,316
D3	3	3·96	32/1,200	35/1,200	1,708
DX3	3	3·96	36/1,500	39/1,500	1,708
D4	4	5·28	42/1,200	46/1,200	2,100
DX4	4	5·28	48/1,500	52/1,500	2,100
FD4	4	5·92	48/1,200	52/1,200	2,128
E3	3	7·35	60/1,200	66/1,200	2,800
E4	4	9·8	80/1,200	88/1,200	3,892
E4S (supercharged)	4	9·8	80/1,000	88/1,000	4,032
E6	6	14·7	120/1,200	132/1,200	5,712
E6S (supercharged)	6	14·7	120/1,000	132/1,000	5,824
F3	3	10·08	80/1,200	88/1,200	2,900
F4	4	13·44	106/1,200	116/1,200	4,000
F4S (supercharged)	4	13·44	106/1,000	116/1,000	4,140
F6	6	20·16	160/1,200	176/1,200	5,800
F6S (supercharged)	6	20·16	160/1,000	176/1,000	5,940

Ruston & Hornsby Ltd.

These engines are of the four-stroke cycle direct-injection type, the range including both air-cooled and water-cooled models. The YB and YD water-cooled engines have a separate cast-iron crankcase and cylinder block, while the YE has a crankcase of monobloc construction; the cylinders have wet-type removable liners. The YBA, YWA and YDA air-cooled engines have separate cast-iron crankcases and cylinder barrels, with single unit cylinder heads of cast iron on YBA engines, and aluminium alloy on YWA and YDA engines. A forged steel crankshaft is supported in pre-finished, steel backed main bearings. The connecting rods, which are steel stampings with pre-finished large and small end bearings, have an angular split large end to facilitate removal through the cylinder bore. The pistons are of low expansion aluminium-silicon alloy.

The YB engines have a thermo-syphon cooling system, and the YD and YE engines are fitted with a water circulating pump; all engines have thermostatic control to ensure rapid warming up. Cooling of YBA and YWA engines is effected by a centrifugal multi-vaned fan attached to the flywheel, while YDA engines have an axial flow fan belt-driven from the crankshaft. Air is delivered to the cylinder heads and barrels through the easily removable ducting, providing an effective cooling system in ambient temperatures up to 100 deg. C. Efficient air filtration is maintained by heavy-duty oil bath air cleaners.

The lubricating oil system has full flow filtration, and provides pressure feed through internally drilled oilways to the main and large end bearings, camshaft and valve gear (also, on YDA, YD and YE engines, to the timing gear). The pistons and small end bearings are splash lubricated. The submerged gear-type pump is gear-driven from the crankshaft, and permits operation on gradients of up to 1 in 4. The smaller YB, YBA and YWA engines have single unit fuel pumps, operated from the camshaft; the YD, YDA and YE engines have a monobloc fuel pump with an integral governor. All engines are fitted with multi-hole fuel injectors and an efficient fuel filter on the suction side of the fuel pump.

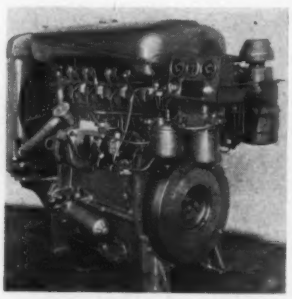
All engines, with the exception of the YE, are capable of transmitting full power from either end of the crankshaft. In addition, YB, YBA and YWA engines have an alternative half-speed drive shaft from the camshaft extension, the YE being arranged for drive to be taken from the flywheel end.

Type	No. of cylinders	Cooling	Capacity (cc.)	Max. continuous rating (b.h.p./r.p.m.)	Automotive rating (b.h.p./r.p.m.)	Max. torque (lb. ft./r.p.m.)	Dry weight (lb.)
1YBA	1	Air	651	6·25/1,800	7·3/1,800	25·5/1,100	549
2YBA	2	Air	1,302	12·5 1,800	14·75/1,800	50·5/1,050	720
1YWA	1	Air	849	9·5/1,800	11·5/2,200	36·75/1,050	540
2YWA	2	Air	1,698	19/1,800	24·5/2,200	76/1,100	680
2YDA	2	Air	2,463	29/1,800	38/2,200	102/1,340	1,056
3YDA	3	Air	3,696	43·5/1,800	55/2,200	154/1,440	1,307
4YDA	4	Air	4,928	58/1,800	75/22.00	204/1,400	1,457
6YDA	6	Air	7,392	87/1,800	110/2,200	306/1,440	1,824
6YDAX*	6	Air	7,392	114/1,800	125/2,200	395/1,320	1,835
1YB	1	Water	651	6·5/1,800	7·2/1,800	24·5/1,160	486
2YB	2	Water	1,302	13/1,800	14·4/1,800	48/1,150	668
2YD	2	Water	2,463	30/1,800	38/2,200	108/1,150	1,090
3YD	3	Water	3,696	45/1,800	58/2,200	166/1,060	1,350
4YD	4	Water	4,928	60/1,800	78/2,200	216/1,200	1,510
6YD	6	Water	7,392	90/1,800	117/2,200	328/1,500	1,888
4YE	4	Water	7,573	75/1,500	82/1,500	289/1,140	2,424
5YE	5	Water	9,465	105/1,800	116/1,800	360/1,140	2,678
6YE	6	Water	11,358	125/1,800	139/1,800	432/1,120	2,932
6YEX*	6	Water	11,358	175/1,800	205/1,800	645/1,390	3,000

* Denotes pressure charged Engine

Standard Motor Co. Ltd.

The two diesel engines manufactured by this company are basically a low-speed model suitable for tractors and industrial applications, and a high-speed model suitable for automotive and marine propulsion. Both engines are water-cooled four-cylinder models with Ricardo Comet V combustion chambers, the swirl chamber being in the crown of the piston. Dry-type cylinder liners are used, and the overhead valves are operated from a duplex chain-driven camshaft.



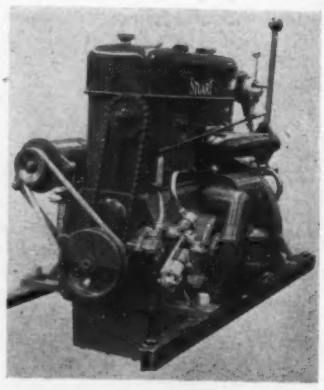
Diesel power pack.

Type	Capacity (litres)	Max. continuous rating (b.h.p./r.p.m.)	Automotive rating (b.h.p./r.p.m.)	Max. torque (lb. ft./r.p.m.)	Dry weight (lb.)
23C	2·26	31/2,000	—	1,040/1,700	617
23CV	2·26	41/3,000	50/3,500	1,160/1,700	590

Stuart Turner Ltd.

The Stuart H2M engine is a two-cylinder two-stroke engine of the loop scavenged open combustion chamber type, air being admitted and the exhaust released through ports in the cylinder wall. Air for scavenging and combustion is supplied by a reciprocating air pump at the forward end of the engine. Inlet and exhaust ports are machined in the cast-iron cylinder block and liners, which are of the dry type. The cast-iron pistons have four compression rings and one scraper ring, the top ring being chromium plated.

The reciprocating opposed-piston air pump is driven from an eccentric on the crankshaft. Air enters through silencers and ciroflex valves, and is delivered through ducts in the crankcase and cylinder block to the inlet ports. These are arranged to give the air a swirling motion which assists complete scavenging of the burnt gases.



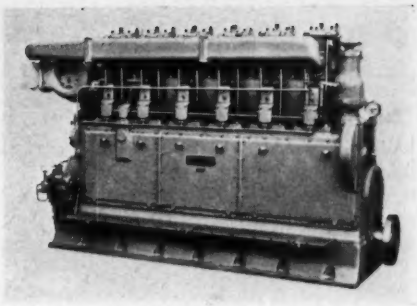
H2M marine.

Type	No. of cylinders	Capacity (cc.)	Max. continuous rating (b.h.p./r.p.m.)	Max. power (b.h.p./r.p.m.)	Max. torque (lb. ft./r.p.m.)	Dry weight (lb.)
H2M	2	778	9/1,500	11/1,500	38·5/1,500	518

Sulzer Bros. (London) Ltd.

In the following table, the ratings of only the smaller B22 series of engines are given. These are four-stroke engines with wet cylinder liners and overhead valves, and are suitable for industrial and marine applications.

Basic type	No. of cylinders	Capacity (litres)	Max. continuous rating (b.h.p./r.p.m.)	Max. power (b.h.p./r.p.m.)	Max. torque (lb. ft./r.p.m.)	Dry weight (lb.)
4T 24	2	72·38	300/400	330/413	4,200/413	16,500
4B 22	4	48·68	185/600	203/600	1,775/600	10,500
5B 22	5	60·85	230/600	253/600	2,210/600	12,350
6B 22	6	73·02	280/600	308/600	2,690/600	14,000
8B 22	8	97·36	375/600	412/600	3,600/600	19,400
4BA 22	4	48·68	275/600	302/600	2,640/600	10,450
5BA 22	5	60·85	350/600	385/600	3,360/600	12,300



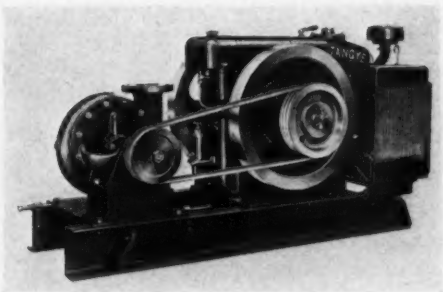
Six-cylinder B22 series.

Tangyes Ltd.

With the exception of the twin-cylinder LD10 series, all horizontal models made by this company are of the single-cylinder type, and all engines are for stationary industrial applications. The P3 engine employs direct fuel injection and a specially designed intake port to promote swirl; all other engines use a combustion chamber of the clerestory type. Wet-type replaceable cylinder liners are fitted in all models.

Type	Max. continuous rating (b.h.p./r.p.m.)	Max. power (b.h.p./r.p.m.)
Twin-cylinder Engines		
ILD 10	110/280	121/280
JLD 10	134/280	147/280
KLD 10	160/265	176/265
LLD 10	190/250	209/250
Single-cylinder Engines		
JL 10	67/280	73/280
KL 10	80/265	88/265
LL 10	95/250	104/250
P 3	12/900	13·2/900
(Two-flywheel type)		
HL 9B	42/295	46/295
IL 9B	50/280	55/280
AWS 6	18/600	19½/600
BWS 6	22/550	24/550
CWS 6 *	26/510	28½/510
DWS 6	32/480	35/480
EWS 6	36/450	39½/450

* *These models are available with a double flywheel, and are known as the W6 series.*



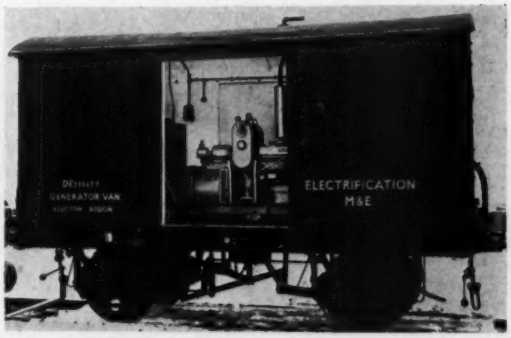
Industrial unit.

Transport Equipment (Thornycroft) Ltd.

All engines are four-stroke direct injection with renewable dry-type cylinder liners and overhead valves. Types JD2, QR6, K6 and K6/S have gear-type timing drives. A chain-gear arrangement is used on the JR6 and NR6/MV.

Type	No. of cylinders	Capacity (litres)	Max. continuous rating (b.h.p./r.p.m.)	Max. automotive rating (b.h.p./r.p.m.)	Max. torque (lb. ft./r.p.m.)	Dry weight (lb.)
Industrial						
JD/2	2	1·39	16/1,800	17·5/1,800*	54/1,500*	700
JR/6	6	4·18	55/1,800	80/2,600	184/1,500	1,000
NR6/MV	6	7·88	82/1,500	100/1,750	322/1,200	1,840
QR/6	6	9·83	113/1,800	130/2,000	430/1,200	1,780
K6	6	11·33	135/1,800	162/1,900	520/1,000	2,650
K6/S (turbo-charged)	6	11·33	160/1,600	200/1,900	625/1,000	2,700

* *1-hr. rating.*



Generating unit.

Turner Manufacturing Co. Ltd.

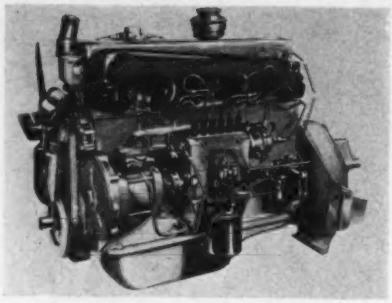
Type	No. of cylinders	Capacity (litres)	Max. continuous rating (b.h.p./r.p.m.)	Max. power (b.h.p./r.p.m.)	Max. torque (lb. ft./r.p.m.)	Dry weight (lb.)
1V95	1	0·815	7·6/1,500	9·3/1,500	29·7/1,400	672
2V95	2	1·63	15·3/1,500	18·7/1,500	64/1,300	728
4V95	4	3·26	30/1,500	36/1,500	128/1,400	1,294

The three engines in the Turner range of diesels are four-stroke water-cooled types, suitable for both industrial and marine applications. Each engine is complete with radiator and fuel tank. The twin-cylinder and four-cylinder models are both of V formation. Direct injection is employed, and the overhead valves are operated by a chain-driven camshaft. Dry-type cylinder liners are used in the 1V95 and 2V95 models, and wet type in the 4V95 engine.

Vauxhall Motors Ltd.

These four- and six-cylinder diesels are primarily for Bedford commercial vehicles. Direct injection is used, a toroidal cavity in the piston crown inducing a swirl action in the combustion chamber. Overhead valves are pushrod operated from a helical gear-driven camshaft, and each cylinder is fitted with a dry liner.

Type	Capacity (litres)	Max. continuous power (b.h.p./r.p.m.)	Max. power (b.h.p./r.p.m.)	Max. torque (lb. ft./r.p.m.)	Dry weight (lb.)
Four-cylinder	3·28	57/2,600	64/2,800	143/1,400	785
Six-cylinder	4·92	80/2,600	88/2,600	210/1,400	994

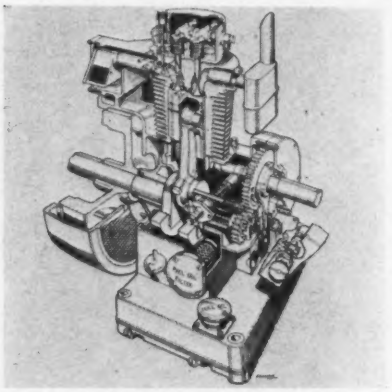


Six-cylinder automotive unit.

Villiers Engineering Co.

This company has recently developed a new vertical air-cooled diesel engine of 269 c.c. capacity. This engine is a single-cylinder model working on the four-stroke principle, the overhead valves being operated by a gear-driven camshaft. The combustion chamber is to the Ricardo Comet design. Extensive use has been made of aluminium, and the total weight of the engine is claimed to be considerably less than that of any other diesel of comparative capacity.

Type	No. of cylinders	Capacity (cc.)	Max. continuous rating (b.h.p./r.p.m.)	Max. rating (b.h.p./r.p.m.)	Max. torque (lb. ft./r.p.m.)	Dry weight (lb.)
D.270	1	269	4/3,000	4½/3,000	95/2,500	160



Section through D.270.

The Coventry Victor Motor Co. Ltd.

The Vixen, type HDW, is a twin opposed cylinder, water-cooled, four-stroke industrial engine developing a maximum continuous rating of 19·6 b.h.p. at 2,000 r.p.m., with a maximum rating of 24 b.h.p. at 2,250 r.p.m. The camshaft is driven by duplex roller chain.

The Coventry Victor Marine type HDW (Mk. 2) is a water-cooled twin diesel similar to the industrial engine; its maximum rating is 30 b.h.p. at 2,500 r.p.m., with a maximum continuous rating at 27 b.h.p. at 2,500 r.p.m.

The English Electric Co. Ltd. have drawn our attention to the fact that the L2K engine mentioned on page 759 of the December issue is in actual fact designated 4RK; in addition, the smallest engine which the company make is the 3K, not the one mentioned above.

SANDWICH CONSTRUCTION

STAINLESS steels and other high-temperature alloy materials planned for the structure of supersonic aircraft have much higher unit strengths than aluminium alloys, and consequently much thinner gauges of material can be used for given load applications. Thin sections, however, are inherently unstable under compression loading, and it has become necessary to design a new structure that will permit effective use of thin materials. This need has led to the widespread development of low-density sandwich panel structures composed of thin face sheets attached to a thick, lightweight, stabilising core.

Because of the rapid introduction of this type of structure in the aircraft, aircraft engine and missile industries, serious problems have arisen concerning the availability of production equipment and processes capable of producing both the sandwich structure and the low-density core panels. A recent study* investigated the application of steel honeycomb and other elevated temperature sandwich structures to the manufacture of aircraft and missile components; the published report summarises the findings of the research.

* *"Present Status of, and Future Outlook for, All-metal Sandwich Construction for Air Vehicles", at Stanford Research Institute, sponsored by the Department of Navy, Bureau of Aeronautics, Industrial Planning Division, Washington, D.C.*

SILICONE BINDER FOR ASBESTOS

A NEWLY developed silicone emulsion prepared by Wackerchemie G.m.b.H., of Germany, meets the requirements of industry for improving the water resistance of asbestos paste board and asbestos moulded articles. This emulsion is being used also as a binder in preparing asbestos paste board, instead of the glue hitherto used.

The tensile strength of 2-mm. asbestos sheets made in the usual manner is about 13 kg./cm.^{2} in the rolling direction, whereas that of asbestos with silicone is about 50 kg./cm.^{2}. After 24 hr. at 250 deg. C. values of 3 and 50 kg./cm.^{2} respectively are obtained. The tensile strength of the silicone asbestos sheet is considerably greater, not only lengthwise but also cross-wise to the rolls direction.

The tensile strength of water-stored silicone asbestos sheets is said to be even more impressive. Whereas the normal asbestos sheet is softened to a slurry, the silicone asbestos sheet retains 80-100 per cent of its original strength.

The water absorption of the silicone-treated asbestos sheeting, as determined by the Kubelka method on a 5-mm. thick sheet, varies between 4 per cent for a period of 10 min. and 12 per cent for a period of 24 hr. With the usual trade asbestos, the figures are generally 78 and 120 per cent respectively.

ENGINEERING APPLICATIONS OF ISOTOPES

Uses of Isotopes are growing in variety and becoming of wider engineering interest. New techniques of value to engineers were reported recently at a conference in Copenhagen

by A SPECIAL CORRESPONDENT

THE success of the recent Conference on the Uses of Radioisotopes in the Physical Sciences and Industry shows that the subject is entering a new phase of development. Organised in Copenhagen by the International Atomic Energy Agency, it was attended by 500 scientists from forty countries and eleven international organisations. A new feature was that many delegates came from technical and industrial groups, and a large number of the 150 papers were related to industrial applications. Dr. John Putman, of the U.K. Wantage Research Laboratory, commented that the conference had shown how methods proposed several years ago had been developed, and in many cases put to practical use.

Below we refer to some of the papers on tracer applications likely to be of special interest to engineers.

Research on Lubrication and Wear

Dr. R. B. Campbell and Dr. L. Grunberg, of the National Engineering Laboratory, East Kilbride, presented two papers illustrating the use of radioactive tracers. In the Lubrication and Wear Division of the Laboratory, the quantitative relation between metal transfer and boundary friction is being studied as a function of sliding velocity, surface roughness and presence of lubricants. To determine the distribution of wear, cast-iron plugs containing Iridium 192 have been inserted in the liners of a diesel engine, and the radioactivity present in oil samples measured. In addition, radioactive iron and iron oxide particles are being used to examine their role in the wear process.

Pure hydrocarbon oils are unable to prevent surface damage, such as scoring or scuffing, of hypoid gears when the conditions of loading or speed are severe. Surface damage can be prevented by adding to the lubricant chemical compounds containing sulphur, phosphorus and chlorine separately or together. These additives react chemically with the metal of the gears to produce easily sheared surface films which provide protection and lubrication. Local high temperatures result from severe loading and accelerate the chemical reaction. A clear understanding of the kinetics of surface film formation at high temperatures is therefore of considerable technological interest. Temperatures up to 700 deg. C. are believed to occur, for short periods, when gear teeth come into contact.

Previous investigations had been carried out at 200 deg. C., and it seemed interesting to extend the range of experimental data to more realistic conditions. The temperature flashes were simulated in an apparatus in which short pulses of electric current were used to heat a wire immersed in mineral oil containing additives labelled with Sulphur 35. This method of heating had been used in the Shell Laboratories at Thornton. High surface temperatures could be reached, whilst keeping the bulk oil temperature relatively low. The use of labelled additives enabled the extent of reaction to be determined, with an adequate degree of accuracy, by measuring the radioactivity acquired by the wire. Both the mechanism and the rate of reaction were determined by studying the phenomena as a function of time and temperature. The effect of other additives in solution, and of preformed films containing S, P, Cl or O was also studied.

Pulses of electric current, lasting 4 ms., each followed by a rest period of 40 ms., were passed through the wire immersed in oil containing the additives in radioactive or inactive form. By using a mechanical rotary switch to interrupt a battery supply, pulses of reasonably rectangular shape were obtained. The temperature of the oil remained well below 100 deg. C., even after pulsing for a considerable period. The voltage across the wire was recorded on an oscilloscope. The wire was supported between electrodes so that, after a radioactive film had formed, the wire and the electrodes could be transferred to a lead castle containing an end-windowed Geiger-Müller counter. By comparing the optical density of the autoradiographs with that produced by a series of calibration spots containing known amounts of Sulphur 35, it was possible to obtain the amount of sulphur in gm./sq. cm. of surface area. The latter could then be transformed into values of average film thickness (see Fig. 1). Elemental sulphur (S) and dibenzyl disulphide (DBDS) containing radioactive Sulphur 35 were used in the experiments, dissolved in liquid paraffin. When the effect of other additives, containing chlorine and phosphorus, on the reactivity of the sulphur additives was investigated, they were employed in concentrations corresponding to 0·5 per cent by weight of Cl or P. The other additives were tributyl phosphate (TBP), tricresyl phosphate (TCP) and chlorinated paraffin wax (CPW).

The results of the film thickness calculations were, whenever possible, correlated on the basis of the generalised "parabolic" law, which is applicable to the formation of surface films when two different processes can be rate-determining. This law reads

$$d^2 + k_1 d = k_2 t \qquad \ldots . (1)$$

where d = the film thickness, t = the reaction time, and k_1, k_2 = constants. Since, under the conditions of the experiments, the reaction could be assumed to occur only during pulsing, the number of pulses, N, could be substituted for t in the equation.

Most of the results obtained followed Equation (1) very closely. It should be noted, however, that all the values of k_1 were *negative*, which suggests that, whilst following formally the generalised "parabolic" law, the assumptions on which the law is based cannot apply to the results. In order to explain these negative values, the following hypothesis was put forward: "The reaction of sulphur or sulphur compounds with ferrous surfaces, under pulsed conditions, in the range 400-600 deg. C. proceeds at first by a very fast reaction. The first few pulses build up a relatively thick surface film, which presents an additional resistance to the

growth of the film by a diffusion process. It seems possible that the change $FeS + \frac{1}{2}S_2 \rightarrow FeS_2$ may determine the change from the fast to the diffusion reaction."

Dr. Campbell, who is Head of this Section of the Laboratory, concluded that, using radioactive tracers, it was possible to elucidate the mechanism of surface film formation and to investigate the various factors which were of importance.

Wear Studies in Other Countries

From the U.S.A., J. E. Howes and colleagues of the Battelle Memorial Institute reported "unique technological results" based on their applications of tracers in large diesel engines. They investigated lubrication and wear in these engines on a scale not before considered practical, with perfect safety. Both lubricating oil consumption and cylinder liner wear were evaluated as a function of operating conditions on diesel engines in the 1,000-b.h.p. range. Techniques were developed for tapping 200 gall. of lubricating oil with 60 millicuries of Zinc 65, and determining oil consumption by exhaust gas sampling during operation under a variety of conditions. Measurement of the rate of lube oil consumption could be made in minutes, rather than the 24-48 hr. required previously.

Irradiation techniques were developed for neutron activation of the lower cylinder portion of a 48-in long, 8-in. dia. cylinder liner. Suitable thermal-neutron shielding allowed the production of 300-day Manganese 54, which resulted in an extending of the useful life of the liner for wear studies by a factor of 6 to 8 over that of a comparable liner thermally activated to produce Iron 59.

The fact that studies with such large quantities of radioactive material can be carried out in standard research facilities in the diesel engine field opens an entirely new area to tracer applications. Selective activation and judicious use of thermal-neutron shielding increases the versatility of the tracer technique in localizing measurement to areas of interest, reducing the total quantity of radioactive material required in wear studies of large parts, and facilitating simultaneous wear measurement on engine parts of identical chemical composition.

A rather different approach employed by U. S. Zaslavsky and G. I. Shor, of the U.S.S.R., was directed to using the tracers for investigating electrokinetic processes and sedimentation in oils with additives containing labelled carbon black. This employed beta counters acting both as radiation detectors and electrodes; these create an electric field, so that the displacement rate of the labelled carbon black in oils containing additives, under the influence of the electric and gravitational fields, can be recorded automatically. The method is suitable for investigating different dispersion systems with a labelled dispersal phase.

The authors defined precisely the essential difference between the requirements for chemical compounds constituting respectively anti-corrosive and anti-friction additives. That difference is the basis of a complex method of investigating multi-component additives having a high anti-friction efficiency but no corrosive action. The method employs radiometric determination of the corrosive effect of oils containing anti-friction additives during interaction with radioactive copper, selection of the most corrosive anti-friction components, choice of effective anti-corrosive components to go with these, and determination of the anti-friction efficiency of the mixture so chosen. Laboratory investigation with radioactive tracers of the neutralising properties of additives mixed with motor oil was used for determining the elimination of these properties when different constituents of additives were mixed in. The results of the laboratory investigations were then compared with data from engine tests.

Wear in the suspension bearing of large turbogenerators was the subject of radioisotopic control, by Kol *et al.*, of Prague, Czechoslovakia. This bearing has a diameter of 3,500 mm., and the quantity of coolant oil used is 31·77 cu. ft. Owing to the large dimensions of the bearing, it was impossible to use standard methods for measuring wear. A new method was evolved whereby a few small areas on the contact surface of the bearing were activated, and the loss in activity measured by a Geiger-Müller counter mounted 20 mm. below the activated bearing. This method was used to study the kinetics of wear on the bearing (made from a material known as K80) used in a turbogenerator set at Slapy hydro power station, from the time the turbine was first started up over a period of 3,600 hr. It was found that the main wear occurs during the first 400 hr.; it is during this period that there is the greatest danger of seizure. Radioactive silver was used to activate the bearing. The accuracy of measurement achieved was high, since it was possible to detect wear of the order of 1-2 microns.

Determining the degree of wear of refractory materials is a problem to which the solutions so far found have been few in number, limited in scope or difficult to apply. For this reason, suggested R. Hours (of Saclay, France), the success achieved in the use of radioactive tracers bedded in the refractory substance has been widely welcomed. Unfortunately, development of the method has been hampered by the fact that the amount of radioisotope incorporated in the metal products must be strictly limited, and also by the diffusion of the radioactive substance in the refractory material. As a consequence, the maximum content permitted in France is now 1 millicurie per 500 metric tons of cast metal, and no individual source may exceed 3 millicuries. At Saclay, sources specially designed to avoid diffusion phenomena have been developed. The essential feature is the use of pyroceramic, a non-porous material with a high fusion point and great chemical inertness. In these sources the radioisotope can be completely enclosed in the pyroceramic, or it can form an integral part of its composition. A comparative study of the two types of source is at present in progress.

Flow Patterns and Leak Detection

In the Isotopes Section of the Australian Atomic Energy Commission, during the last two years, a study of the flow pattern of water in a power station cooling pond has been the subject of two extensive experiments. J. N. Gregory described how a small volume of the warm condenser water was labelled with Iodine 131 (as iodide in solution) as it entered the pond. The subsequent flow of this water was followed quantitatively throughout the 200,000,000-gall. pond by the use of calibrated underwater scintillation counters. With 500 millicuries of tracer it was possible to plot the flow pattern until mixing was complete. In one case this took six to seven days. A recording scintillation detector at the power station pump house measured the rate of return of the labelled water to the power station. These experiments also showed that the flow pattern was affected by the wind more than by any other factor. A wind opposing the normal hydraulic flow consistently reversed the flow at a quite moderate wind velocity. In the absence of wind an appreciable fraction of the warm water channelled across the surface of the pond and re-entered the power station within 3-4 hr. This indicated a design defect in the layout of the intake, which was subsequently modified. The season of the year also had an effect on the flow pattern.

Flow was also examined in a Bach subsider for raw sugar solutions. The hot raw solution, after lime treatment, enters through a single feed line at the top, and clarified solution is taken off by pipelines at six different levels. The solids are taken off at the base. About 5 millicuries of Bromine 82 in solution was injected into the feed line, and the appearance of the tracer measured quantitatively by shielded scintillation detectors on each of the six outlet

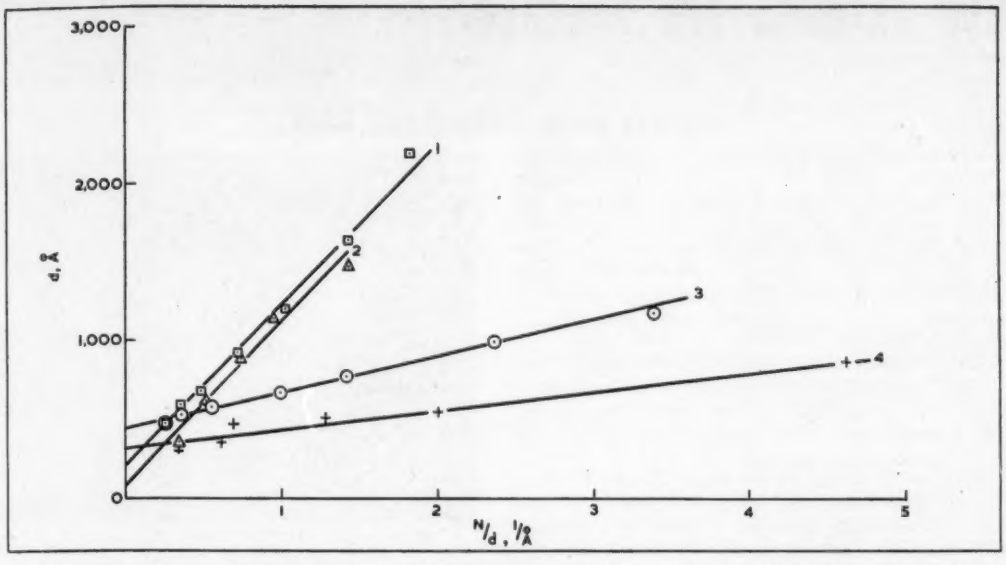


Fig. 1. Illustrating the relation between film thickness, d, and number of pulses, N, using mild steel and a pulse temperature of 400 deg. C. (1, 2, dibenzyl sulphide; 3, 4, elemental sulphur.)

pipes. Analysis of the distribution of activity with time in each line permitted a clear indication of the nature of the flow within the subsider.

From the U.K. Atomic Energy Authority came a contribution, by C. G. Clayton and J. W. Webb (of Wantage), on continuous measurement of volumetric flow of gas in turbulent and streamline condition using a small radioactive source mounted on a hinged gate. The use of radioactivity enables measurement of the gate inclination to be made outside the pipe, thus in the author's words "establishing the pattern of a simple instrument". The use of penetrating radiation also results in an extension of the operating range, since it permits the use of a multi-gate system. An external detector then gives simultaneous measurement of the resultant inclination of several gates. The paper went on to give relationships between volume flow and detector current for single and multiple gate systems.

Radioactive gases provide a method of leak detection in hermetically sealed components which in specific cases can be more sensitive by several orders of magnitude than conventional methods of leak detection. J. F. Cameron and P. F. Berry, also of Wantage, described the use of Krypton 85 for this purpose in two distinct ways. The first method is to immerse the component in the gas under controlled conditions of pressure and time, and measure the amount forced in under pressure by subsequent monitoring of the radiation transmitted through the walls of the component. In the case of walls of thickness greater than 250 mgm./sq cm., this is a combination of *Bremsstrahlung* and gamma rays. In the second method some active gas is inserted before sealing, and the subsequent loss of activity is a measure of the leak rate. The method chosen depends on the dimensions of the component and its proposed use. Filling the component with even small quantities of radioactive gas is undesirable from a health point of view.

The chief limitation on the sensitivity in the first method is surface contamination due to absorption of the gas into the pores of the component material, and corrections have to be made. Allowing a time of 1 min. for monitoring each component, leak rates of the order of 10^{-13} c.c. N.T.P./sec. are detectable. Generally speaking, the larger the component, the lower the sensitivity, so that to achieve 10^{-12} c.c. N.T.P./sec. with thermionic valves it would be necessary to devote an hour to each measurement. Prefilling of the component with active gas before sealing has two advantages. It permits an evacuation test and subsequent monitoring of the egressing gas to evaluate the leak rate with a sensitivity comparable to the helium mass spectrometer; furthermore, long-term monitoring of the contents of the component is possible. This obviates a leak closing up temporarily during the short-term pressure or vacuum test, and provides an integrated value which is more useful.

Storage Capacity of Batteries

According to the literature, the shelf life of a silver-zinc storage battery is not influenced by whether it is in a charged or discharged state during storage. This statement is in contradiction to the results obtained during investigations on the cell mechanism. Consequently, Tivadar Palágyi, of Budapest, Hungary, carried out experiments with radioactive tracers on cells, manufactured in the laboratory, having a nominal capacity of 10 amp. hr. In every case one labelled electrode was built into the middle of the cell, and test cells were stored in the charged and discharged condition respectively. Altogether thirty-two cells were built—sixteen cells with a negative electrode labelled with Zinc 65, and sixteen cells with a positive electrode labelled with Silver 110. Both isotopes were electrolytically deposited on the electrodes. After filling the cells with electrolyte, and after three charging and discharging processes, eight cells from each of the Zinc 65 and Silver 110 labelled groups were stored in a charged, and eight in a discharged, state. From each of the resulting four cell groups, two cells were opened after one month's storage, and two cells were opened after two, three and six month's storage respectively. The activity of the electrodes was measured with a cylindrical GM-tube, and the electrodes were replaced into the casing with the order unchanged. After the reassembly and filling of the cell with fresh electrolyte, the cycling for determining the cell life was started.

The experiments proved that while storing cells with a labelled negative electrode, both the positive and negative electrodes dissolve to a certain degree. The unlabelled electrodes of cells stored in a charged state were contaminated in a higher degree, and after storage these cells yielded fewer cycles than the cells stored in a discharged state. From this fact it can be inferred that storage in the discharged state is more favourable than in the charged state.

NEW IDEAS IN DESIGN

Outstanding products in current manufacture

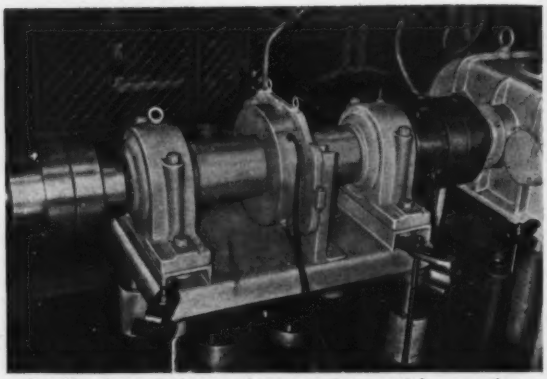
Torque Gauge without Slip Rings

IN many industries there is a need for a torque gauge for rotating shafts, which are often of large diameter. In most installations a reduction of the existing shaft diameter is not permissible, and in many cases it is impossible to insert a special calibrated measuring shaft. Thus the torque measurement has to be performed on the existing shaft, to which the least possible modification should be made, and in many cases only a rather short free length of a few inches is available.

Two different basic principles are generally used in torque meter design. One involves measuring the torsion over a certain shaft length with some form of displacement gauge, the other is based upon direct measurement of stress or strain in a short section of the shaft.

In order to overcome the disadvantages in these methods of having to use a substantial length of shaft or employ slip rings, a new system has been evolved by Allmänna Svenska Elektriska Aktiebolaget, of Sweden. This method, which directly measures the stress in a short section, is based on the fact that the permeability of steel is changed by stress. By placing an iron-clad stationary coil around the shaft, the change in the inductance of the coil may be used to determine the torque. For small torque values, the increase in permeability in the tensioned 45-deg. direction, and the net change in longitudinal permeability, is thus zero for small torque values, giving zero sensitivity within this range. The torductor, primarily intended for heavy shafts, eliminates this disadvantage. Two types have been developed, the cross torductor and the ring torductor.

The ring torductor consists of three identical pole-rings with a number of poles that is always chosen as a multiple of four, to reduce the influence of the ring joints necessary for easy mounting of the torductor around the shaft. The poles are fitted with coils having alternately reversed winding directions. The middle ring is displaced half the pole-pitch relative to the outer rings, and the distance between the rings is approximately equivalent to half the pole-pitch. The middle ring is normally used as primary, and excited at 50 or 60 c/s. The two outer rings are used as secondaries and connected in series, with reversed winding directions.



Combination of ring torductor and a special measuring shaft applied to the testing of gearboxes.

A ring torductor half.

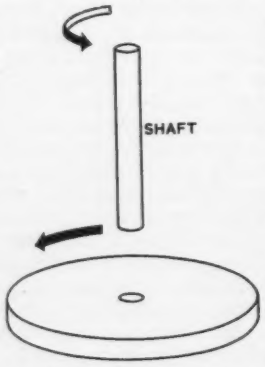
If the shaft is un-loaded and without internal stresses, the magnetic fields between the different North and South poles will be symmetrical, so that the zero equipotential lines will be situated symmetrically under the secondary poles. The secondary flux, and hence the secondary voltage, is thus zero at zero stress. When torque is applied to the shaft, the principal stresses are obtained. The permeability in the direction of tension between poles is then increased, while the permeability in the direction of compression between poles is decreased. The resulting fluxes through the poles co-operate in inducing an output voltage in the series-coupled windings, normally of the order of 10 V at 1 mA.

As the ring torductor measures almost uniformly around the shaft, the 45-deg. stresses are virtually integrated around the circumference, the modulation of the output voltage being thus reduced to a very small value and the accuracy of the static calibration being of a high order.

The effective response time of the ring torductor is mainly determined by the exciting frequency and the desired degree of filtering of the output signal. For 50-60 c/s excitation, it can be of the order of 10-30 millisecond, dependent on the circuitry chosen.

PROBLEM IN DESIGN No. 15

Here is this month's problem



1 COMPLETE REV. PER MIN.
12 DWELLS OF APPROX. 5 SECS. EACH

In a piece of display apparatus it is necessary to provide a means whereby a slowly rotating shaft will cause a display disc, having the same axis of rotation, to move round in a series of dwells.

Data: display disc, approximately 18 in. in dia., completes one revolution per minute, this being accomplished in twelve dwells of approx 5 sec. each. Since the display is suspended, no obvious means of torque constraint must be apparent. The motive power for the shaft will be an f.h.p. motor, concealed overhead.

Best solutions to "Problems in Design" are published and paid for. Send your solution for this month, with a drawing or diagram (in Indian ink and not more than 12×12 in., please!), to the Editor, "Problems in Design No. 15 (January)". Closing date February 20.

In order to give overseas readers more time to submit their entries, the period allowed has been extended. Solutions to Problem in Design No. 12 (October) will appear in the February issue.

New Type of Expansion Joint for High Pressure Ducting

AMONG the numerous incidental engineering problems facing the designers of atomic power stations is the one of accommodating the considerable thermal expansions of the ducting conveying the coolant gas from the reactor to the heat exchangers.

The operating pressures and conditions and the duct sizes are such that telescopic-type expansion joints cannot be used, because of the magnitude of resulting unbalanced end thrust, and the usual solution is to provide in each leg of the ducting three flexible "pinjoints", and to accommodate the expansions by angular deflections. The expansion joints must therefore be capable of transmitting the axial duct thrusts, amounting in some cases to over 1,000,000 lb., while at the same time allowing a predetermined amount of angular deformation. A more or less conventional convolution-type bellows can be used to provide a gas seal, but the restraint mechanism transmitting the axial thrust presents a difficult engineering problem.

Existing solutions fall, broadly speaking, into two categories. One uses what amounts to a pair of hinge pins, placed on both sides of the duct, the other a flexible tongue inside the duct, while some designs combine both. The difficulty facing both designs is the necessity of transmitting the peripherally uniformly distributed axial duct forces into one axial plane; thus, extremely heavy structures stressed mostly in bending are required. Furthermore, all the available designs can deal with deflections in one plane only, so that any misalignments at right angles to the normal deflection plane impose uncontrolled loads on the components of the circuit. Pinjoint-type restraints contain also the inherent danger of fretting and possible seizure, if one considers that they may have to deflect after remaining in one position for a considerable time.

A new type of restraint, which is claimed to deal in a satisfactory manner with all aspects of the problem, has recently been developed by Richardsons Westgarth & Co. Ltd. It will be first used in the Trawsfynydd atomic power station, at present under construction. The accompanying diagram shows the mechanical configuration of the restraint, and the photograph the full-scale test rig on which the required fatigue tests have been accomplished.

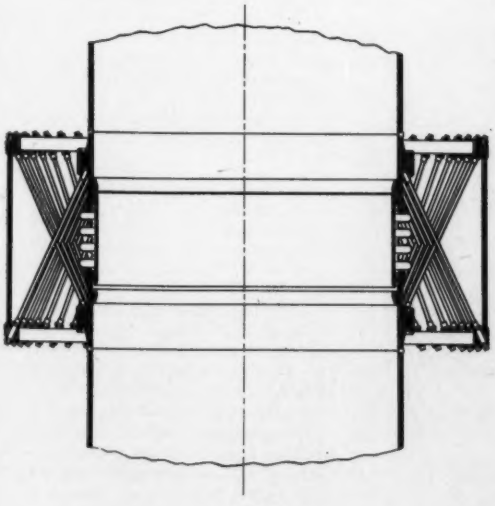
This restraint works entirely on elastic deformation principles. A multiplicity of high-tensile bars, arranged in two groups into two frusto-conical assemblies, and spaced uniformly around the periphery of the duct, transmit entirely uniformly the axial forces. In the axial direction the joint behaves as a stiff connection, but it can deform angularly by transverse bending of the bars. The deformation of the restraint is achieved by pure elastic deformation of the restraint bars, so that the forces involved are both accurately predictable and not variable in time. Furthermore, the complete rotational symmetry of the restraint makes it equally flexible in any direction.

A wide range of working deflections and restoring moments can be accommodated by varying the basic dimensions of the restraint, the number and size of the tie-bars, and the cone angle. In the restraint shown here the bars have been actually overcrossed, resulting in a small overall length.

A centring device connecting the two duct stub ends ensures that no torque loading can be applied to the convolutions, and equalises the deflections of the two sets of bars under conditions of steeply changing bending moment along the duct. The shear force accompanying such a change of bending moment is taken entirely by this device, leaving the bellows free of this additional loading. A further advantage of the design is that the completely transparent and accurately calculable stress system allows a close approach to an ideal shape in the tension bars.

Apart from the obvious advantages of a uniformly stressed structure, and the elimination of the dangers of fretting or seizure, the gimbal joint characteristics of the restraint offer much greater freedom to the nuclear station designer. Considerable saving in civil engineering work can be achieved under certain circumstances if the coolant circuits need not be kept in one plane.

Apart from the work on nuclear applications of the restraint, Richardsons Westgarth are investigating its use in other applications requiring high-pressure and high-temperature ducting, including, among others, designs for operating temperatures of the order of 600 deg. C.



LETTERS TO THE EDITOR

Design Diploma

Sir,

I read your editorial "No Design Diploma Yet", in the October issue, with interest. It would be very difficult indeed to decide from an examination whether a person was qualified to hold such a Diploma. Some individuals have exceptional creative ability, and I prefer to call these people inventors.

The majority of designers have varying degrees of creative ability, but most of their work is in the improvement and development of existing designs. Therefore, a first-class designer requires not only high technical ability but a very wide experience of existing equipment.

In my opinion, a Diploma for Designers would be "just one more diploma" to roll up and put in a drawer. Membership of one of the leading engineering institutions is more likely to receive recognition by employers.

Nevertheless, designers should strive to improve their status, especially those thousands of first-class men in drawing offices. If they would change their employment description from designer draughtsman to engineering designer, a step forward would be achieved, and the union concerned should recognise help in this change. Some enlightened employers already recognise the difference and advertise accordingly.

If the A.E.S.D. could alter its title to Association of Engineering Designers and Draughtsmen, a further step forward could be made.

It is high time that the status of good men who have studied diligently and gained first-class experience should be improved, and I think it is essential that these men should have the title Engineering Designers. Another point which springs from this aim for better status is the fact that engineers as a body are too self-effacing in this country.

In every engineering office the names of the staff with their technical qualifications and membership letters of Institutions could be displayed for all to see. If this were done, the opinions expressed and suggestions offered by engineering designers would receive more respect from management.

Another point is that in these days of larger and larger companies and nationalised concerns, staff departments have more say in appointments—it is not advisable to cloud their minds with too many types of diplomas. They are interested in O.N.C., H.N.C., Degrees, membership of the leading technical bodies and the description of the posts. In their minds, any grade of draughtsman is a draughtsman and any grade of engineer is of higher status.

Finally, with reference to your editorial, your suggestion that a designer should broaden his scope by learning a foreign language is good, but I suggest also a study of elocution and speech making to enable him to express properly his ideas. Many a good suggestion is lost because the contributor cannot express himself with clarity and power.

London, S.W.1.

M.I.Mech.E.

Sir,

Mr. A. A. Witham's letter (page 713, November) outlining the course leading to a Dip. Mech. Des. is most interesting and welcome. Such a course is long overdue and will be most valuable to industry in general, and I hope that employers will permit and encourage their staff to take it. I would like to put forward a few suggestions.

Referring to paragraphs 1 and 3, I hope that the courses will be specialised. After all, an excavator equipment and a pressure gauge are both mechanical equipment, but the design problems are of a very different nature.

Paragraph 6: When each completed project has been submitted and studied by the board of examiners, the candidate should be asked to attend a meeting at which the project is discussed in detail. The board and candidate can then clarify any disputed ideas. This can never be achieved satisfactorily by correspondence.

Paragraph 7: I am unhappy to see that Mr. Witham still wishes to retain the ancient examination system—no notes. What does he wish to examine, the candidate's memory or his design and inventive ability? Why should a designer be burdened to remember facts he can, and would, look up in practice! In practice it is much more important to know where to find the information than to know it.

G. T. Schwartz

Sangamo Weston Ltd.,
Great Cambridge Road,
Enfield,
Middlesex.

Pay for Apprentices

Sir,

Your editorial in the August 1960 issue, entitled "Pay for Apprentices", hit a very "sour note" with the writer.

While admittedly I am not too well versed with the actual conditions in British industry, I had to relate the editorial to industrial conditions in this country.

The apprentice or indenture system used in the United States is based on the British thinking. We have been using it in about the same way for the past 150 years. We have found that many of the leaders of American industry have been the product of the system, and we have been able to enjoy and obtain industrial growth under their leadership. We have developed most of our top-flight mechanics, many engineers, inventors and technicians through the apprentice system.

Recently we have found that the system is not sufficient to maintain this industrial growth. We train a large number of engineers in our colleges and universities, and many of them are rated with the world's top scientists. We also train a large number of technical personnel to operate our machines and equipment and to do the routine work connected with industry. We do, however, have a marked shortage of men to cover the in-between range—the gap between the man on the machine and the engineer. Here we both must rely upon the apprentice-trained technician, the craftsman, tool designer, production engineer, the tool and die maker, the gauge maker, and others of these classes that can only obtain their craft know-how and skill through on-the-job training, plus technical schooling, usually found "off-the-job".

In our opinion, our industrial development will grow only in proportion to the availability of this type of trained person.

We who are close to this type of training disagree that industry should obtain this type of personnel at no cost, and we also disagree that industry does not get value received from properly selected apprentices, from the first few months they are on the job.

We have found that properly selected apprentices, properly trained, are capable of performing journeyman's work after two years' intensive training. This intensive training does not allow industry to use a trainee as "cheap labour" and to do routine monotonous tasks. If industry is really interested in obtaining technicians, they can make them in this short length of time.

We select our apprentices through a rigid examination, plus physiological testing. They are usually men over the age of twenty-one and are earnestly desirous of such training. We pay them a wage to start that is 55 per cent of a journeyman's top wage, and raise them every six months for the duration of their apprenticeship until at the end of two years they receive 75 per cent of a top journeyman's rate.

Our labour statistics indicate that with all our efforts to attract qualified men into technical training we are still unable to keep up with those who leave the trades through death or old age. This is a very serious problem with us.

We feel that the old apprenticeship rules and thinking are a thing of the past, and we cannot quite understand how anyone of this day and age could endorse your editorial.

May we hear further from some of your readers on this subject?

Robert W. Burgess

The Greist Manufacturing Co.,
New Haven, 15,
Connecticut,
U.S.A.

Problems in Design

Sir,

I must congratulate you on the quality of your reproduction of my solution to Problem in Design No. 10 (p. 685, November), especially considering the deficiencies of the original, but my real reason for writing is to point out that you have unfortunately misinterpreted the mode of operation.

In the sketch on p. 687 you have entitled the two shafts "drive" and "driven", just as I intended, but in your description you

have reversed their functions, saying that the bushed pins are driving the links, which should have been vice versa.

As this should have been, the result produced is that when the device trips, the links continue to rotate with the motor until it stops. Now due to the geometry of the links and the spring constraints, as well as to the position of the centres of gravity of the links, these will swing out to their extreme positions just as soon as the action of tripping commences.

This is aided by the fact that not only does the centre of gravity move outwards to increase the magnitude of the centrifugal force, but the line of action of the latter changes to further increase its moment on the drive link, and at the same time the restraining moment exerted by the spring actually decreases. In addition, as soon as the device begins to trip, the moment exerted on the drive link due to torque rises very quickly indeed and far quicker than the torque itself.

Thus the change from normal drive to trip is very rapid, and the stop switch should receive only one blow to operate it.

I very much regret that I did not make myself clear in the first place, but I trust that you will now more fully understand my intention.

D. C. Wood

44 Breedon Hill Road,
Derby.

We regret our error in stating that the bushed pins in this mechanism drive the links, the reverse being the case. The fact that the links are directly driven by the motor right up to the instant when the micro-switch is operated would ensure the speed and positiveness of the cut-off.

Sir,

In defending his solution to Problems in Design No. 8, Mr. Tindale states: "Some have chosen to ignore the requirement" ("Letters to the Editor", page 713, November). He appears to have studied the published entries with less diligence than your adjudicators, and I can find none that has incorrect direction of rotation.

H. T. E. Hone

48 Hampton Court Avenue,
East Molesey,
Surrey.

"Keeping in Touch"

Sir,

The fact that "It is sometimes easier to initiate a practical programme of research than to find out what has been done before" has been described as "A scathing criticism of existing information services" (editorial, November, 1960).

Of course, if we can find just what we want already made by someone else, there is no point whatever in going over the same ground again. But how often does this happen? It is rare to find that the precise conditions defining our present work have been met in former cases. The latter, if known, may outline a principle and give a guide to its possibilities of application. To adapt it to our own needs, however, may need almost as much basic thought, and design work, as if we were starting from nothing.

This major adaptation work will almost certainly be needed in any case. If the organisation concerned is really capable of doing it, little more may be required in many cases for starting from scratch.

Apart from this, although "a search of the literature" seems to be a normal start for research, the engineer actively engaged in design work usually has little time for this. It must be done at his own level of thought, and cannot effectively be delegated as, as a rule, only he can assess the value of what is presented. Abstracts, as a rule, are of little value in sorting the relevant from the remainder.

The dilemma of keeping the busy creative man in touch with other past or parallel activities remains. We should know something about what is being done elsewhere, and benefit from it where we can; but unless we are to rely entirely on others, we must keep our own thinking caps in good working order.

Hugh Clausen

17 Harman Drive,
London, N.W.2.

Self-lubricating Bearings

Sir,

I should like to draw your attention to the article "Self-lubricating Bearings", (page 627, October), where, in the third paragraph, Fluorosint bearing material is compared with Glacier DU. It would appear that the figure quoted by us in Table 4 of less than 0·001 in. at 16,000 p.v., and Fig. 3, where the wear characteristics of Fluorosint are shown, have been taken as the basis for comparison. However, this "less than 0·001 in. wear" is only the order of wear in comparison to the other materials shown in Table 4. It must certainly not be taken to indicate that DU has a p.v. limit of 16,000. Incidentally, a p.v. of 16,000 in a unidirectionally loaded DU bush would result in a probable "life" of well over four years' continuous running. If the load/velocity design limits on page 12 of Glacier's Designer's Handbook No. 2, which are unfortunately not included in the article, are consulted, mating with hard steel, p.v. figures of up to 33,000 are acceptable. This is double the p.v. which can be tolerated by the Fluorosint material. In fact, this latter dry bearing material is more comparable to our DQ type, which is unfortunately not mentioned in the article.

Fig. 1 shows the typical wear/time relationship for the DU dry bearing material, and not for the reinforced p.t.f.e. materials. It will be appreciated that there is an essential difference between the two, as the DU material is steel backed with a porous sintered surface impregnated with a mixture of p.t.f.e. and lead, whereas the reinforced p.t.f.e. materials are basically p.t.f.e. containing various reinforcements such as bronze, graphite, glass fibre, etc. With regard to the wear factor, the DU material has a running-in mechanism, after which the operational wear is very small indeed. On the other hand the reinforced p.t.f.e. materials exhibit continuous wear which is directly proportional to the load velocity and time factor until a point is reached where the clearance reaches an unacceptable level, which is generally taken as the end of the life of the bearing.

In addition, there are some remarks made in the article with regard to low heat transfer rates of p.t.f.e., and though this is perfectly true for pure p.t.f.e., and to a lesser degree for reinforced p.t.f.e., it does not apply to our DU material. Here we have provided a path for the heat dispersion via the bronze matrix and the steel backing. Therefore, no special provision has to be made for the expansion of the material, which is close to that of steel (15×10^{-6} per deg. C.).

There is one other statement which I feel we must contradict, and this concerns the development of static electricity in our dry bearing materials. We specifically point out in our handbook that both DU and DQ do not suffer from static electricity phenomena, and therefore are well suited to atmospheres where "fly" or paper dust is attracted owing to the static electricity developed in some other plastics bearings. DU and DQ are reasonably tolerant of dirty conditions, and it is only in extreme cases that we recommend that the assembly be encapsulated. Incidentally, we do not recommend that copper base mating material should be used with our DU or DQ material, as both of them contain bronze. However, a very satisfactory material not mentioned is anodised aluminium.

The section dealing with fluoro-carbon bearing materials makes mention in its last paragraph of surface treatments based on p.t.f.e., but, unfortunately, our very successful DG process is not described. This has been carried out by us for many years now, and has been very satisfactory in a large number of applications.

I. H Onslow

The Glacier Metal Co. Ltd.,
Alperton,
Wembley,
Middlesex.

The author of "Self-lubricating Bearings" accepts the points raised by Mr. Onslow, but points out that, in the space allocated for the article, detailed evaluation of each company's materials was impossible. In a survey of this type it is assumed that any reader wishing to use these materials will approach the manufacturers at an early stage of design, in order to benefit by their experience and advice.

Rectangular Hollow Sections

Sir,

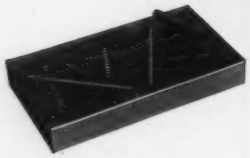
With reference to the article on Rectangular Hollow Sections (p. 546, September), a point worth bringing to the notice of designers is that, with thin wall tubes in bending the modulus of the section is a maximum when the depth is three times the breadth.

J. C. Matthews

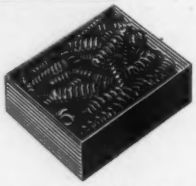
Dunelm,
Kevock Road,
Lasswade,
Midlothian,
Scotland.

EMD 5365 for further information

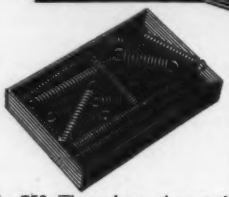
EXPERIMENTAL SPRINGS?



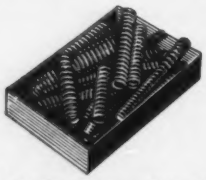
No. 1200. Three dozen Assorted Light Expansion Springs, suitable for carburettor control, etc. **13/6.**



No. 98A. Three dozen Assorted 1″ to 4″ long, ¾″ to ⅞″ diam., 19G to 15G. **5/6.**

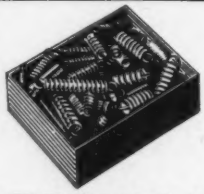


No. 753. Three dozen Assorted Light Expansion ¼″ to ½″ diam., 2″ to 6″ long, 22 to 18 S.W.G. **10/6.**



No. 760. Three dozen Assorted Light Compression Springs. 1″ to 4″ long, 22 to 18 S.W.G., ¼″ to ½″ diam. **6/6.**

No. 757. Extra Light Compression, 1 gross Assorted, ¼″ to ⅜″ diam., ½″ to 2½″ long, 27 to 19 S.W.G. **15/-.**



No. 758. Fine Expansion Springs. 1 gross Assorted ¼″ to ⅜″ diam., ½″ to 2″ long, 27 to 20 S.W.G. **15/-.**

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HT31

OVERSEAS NEWSLETTER

A monthly digest of reports from our foreign correspondents of other countries' current achievements in reseach and development work

Lubricating Films

Solid lubricants are most useful as films which separate metal surfaces that slide against each other. To be effective the films should be highly durable. During the course of some studies at the Research Laboratories of General Electric (U.S.A.) on the frictional properties of lamellar sulphides which crystallise in the CdI_2 system, it was observed that though SnS_2 displayed relatively high friction, it formed excellent films when rubbed over a metal surface. It was further observed that the film properties of MoS_2, which is an excellent lubricant, could be enhanced by adding 10 per cent by weight of SnS_2. However, a number of additional unexpected synergistic effects were also noted, the most important of which was an improved resistance of the films to penetration under highly loaded sliding conditions. Accordingly, an experimental programme was initiated to find other effective sulphide additives.

In the most favourable case the additive increases the seizure load for the film by more than a factor of 20 over that for a pure MoS_2 film. The action of these additives in solid lubricants resembles that of the extreme pressure additives for liquid lubricants. Films of MoS_2 have higher load-carrying ability if they are applied to mild-steel surfaces on which a surface film of FeS has been formed by chemical reaction. Chemical analyses indicate that an active additive tends to be more concentrated in a rubbed film than in the material from which the film was rubbed.

Though the hypothesis of chemical attack by the additives is attractive, the data do not preclude the possibility that effects other than chemical are important in enhancing the adhesion of the film to the metal substrate. Studies carried out indicate that chemical reactions between molybdenum disulphide and the surrounding atmosphere may have a significant effect on lubricating efficiency to an extent not previously appreciated.

Vibration-absorbing Materials

One of the new ways of reducing noise caused by vibrations propagated through rigid elements of machines and metal structures is the application to the vibrating elements of special coatings having high internal losses. The application of these coatings increases active losses in the mechanical vibrations, and thus reduces the proportion of the vibrational energy producing the noise which is radiated. Some vibration-absorbing materials have recently been studied experimentally by Naumkina, Tartakovsky and Efrussi, and written up in a U.S.S.R. Journal, *Akustichesky Zhurnal*.

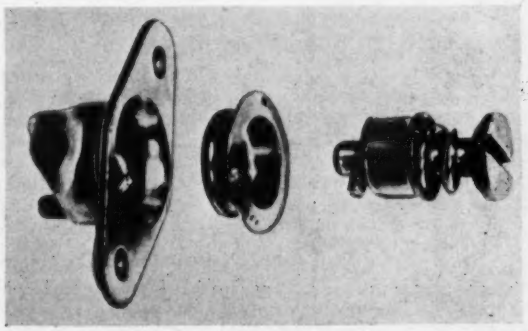
Considering that vibration-absorbing materials are much softer than a metallic rod, an expression for the mean coefficient of loss can be written. With increase in the thickness of the coating, the coefficient of loss of the composite rod approximates to that for the vibration-absorbing coating. Consequently, when the thickness of the coating on a metallic rod is very great, the losses in the rod depend only on the losses in the vibration-absorbing material itself. With thin coatings, the coefficient of loss depends on the imaginary part of the elasticity modulus. In both cases the losses do not depend on the mass of the vibration-absorbing coating. Thus for the application of vibration-absorbing materials with the object of weakening elastic vibrations, it is necessary to measure their mean coefficient of loss and the Young's modulus of the composite rod. Measurements of these properties were carried out under conditions closely similar to those obtaining in practical use, in exciting elastic vibrations of rods at audio frequencies. One of the variants of the method of measurement is when the rod is manufactured from the material being tested (uniform rod method). When the materials being investigated were so soft or thin that it was not possible to produce sufficiently strong rods from them, they were applied in an even layer to a metal strip (the composite rod method). The first method is simpler but can be used only for fairly strong materials, while the second method is universal but has the disadvantage that it requires much greater accuracy in the acoustic measurements.

It was found that one of the best vibration-absorbing materials was felt impregnated with bitumen and coated with mastic on an asbestos base. Further study of vibration-absorbing materials should combine phenomenological investigation of their dynamic characteristics (in particular, frequency and amplitude characteristics of the modulus of elasticity and the damping coefficient) with study of the molecular mechanism of losses of mechanical vibrations. It is also necessary to study methods of rational utilisation of vibration-absorbing material, in order to reduce the weight and thickness of the coatings.

Quick-release Fasteners

Camloc fasteners, which previously could only be purchased direct from the U.S.A., are now available in Europe. The most notable of these is a quick-operating, quarter-turn fastener available in a wide range of sizes, styles and materials. The elements of the 4002 series consist of stud assembly, grommet and receptacle, all of which may be installed with simple hand tools by unskilled personnel. The self-ejecting stud assembly readily adapts to curved or hinged panels, and also acts as a flag if the stud assembly is not fastened.

Camloc also produce other quarter-turn fasteners, stressed panel fasteners, quick-operating hose and cable clamps, electronic and airframe latches. These are described in a catalogue available from Camloc Fastener G.m.b.H., Frankfurter Strasse 36, Kelkheim/Taunus, Germany.



New Books

Engineering Thermodynamics. *By James B. Jones and George A. Hawkins. (John Wiley; Chapman & Hall—68s.)*

An interesting and commendable book, easy to read, which concentrates on the fundamentals of thermodynamics and avoids descriptions of engineering applications. Whilst written for students and lecturers, it should also appeal to practising engineers who wish to refresh and enlarge their grasp of well-established and more modern theories.

The first few chapters dealing with fundamental concepts and definitions, the first law of thermodynamics, physical properties, ideal and real gases, the second law, reversible and irreversible processes and cycles are discussed in detail, with repeated explanations to ensure that the student is completely familiar with these essential concepts. The authors reason that, with this object achieved, a lessening of detailed description can gradually be permitted throughout the remainder of the book, which discusses: entropy, more physical properties, availability and reversability, gas and gas-vapour mixtures, chemical reactions, and chemical equilibrium in ideal gas reactions.

Further chapters include such topics as binary mixtures and heat transfer, concluding with a useful selection of tables and charts. Numerous references for further reading, and a particularly large number of graded problems, are given at the conclusion of each chapter.

R. W. New

Progress in Non-destructive Testing: Vol. 2. *Edited by E. G. Stanford and J. H. Fearon. (Heywood & Co. Ltd.—55s.)*

This volume is the second of a series which is to report annually on progress in non-destructive testing. Some forty years have passed since surface cracks in welds and castings were sought and found by the oil and chalk method. A little later, X- and gamma-radiology was used for the same purpose, but with an increased field because subsurface flaws could be detected. More recently, magnetic particle penetrants, the ultrasonic beam, eddy currents, damping capacity measurement and X-ray crystallography have all been added to the means of non-destructive testing, and the field of operation has expanded greatly to embrace not only or even mainly, the detection of flaws, but also the examination of the properties and composition of materials.

The end to this growth is not yet in sight, and this volume is a worthy successor to the first one in presenting a number of ably written essays on development in the methods of test already mentioned, and also on other physical phenomena, the application of which to routine examination may soon be a fact. The editors deal well with just this aspect of the "assessment of uniformity of quality of materials" in their foreword. They point out that the attention of physicists and engineers must be drawn to techniques which are still in a laboratory stage, but some of which may well be developed for practical exploitation in new methods of testing.

There are seven essays, and, of these, four are concerned with current practice, namely, X-radiology, electrical methods for flaw detection and the study of metal structure, the uses of radioactive isotopes in non-destructive testing, and the ultrasonic assessment of defects. All of them discuss problems which lie, so to speak, in the front line of modern technique. Thus the essay on X-rays deals with the use of megavoltages as compared with the kilovoltages which are standard practice today. In speaking of electrical methods, the author is mainly concerned with the measurement of sensitivity. But he applies the results not only to flaw detection but also to determine fatigue life, phase changes, magnetic domain dimensions and lattice defects in metals.

Radioactive isotopes are today used for gamma radiography and a host of other purposes, including thickness measurement, fluid density measurement, level gauging and tracer investigations. It is particularly commendable that this essay begins with a short introduction on radioactivity and the properties, decay, production and radiation characteristics of isotopes. Many an engineer and physicist whose daily work is remote from radioactivity will be glad of this reminder.

In the case of ultrasonic testing, the spotlight is on the assessment of flaw dimensions, and not only on flaw location. It is a subject much discussed just now, and in the forefront of ultrasonic work. Some advance is recorded, but more remains to be made.

The other three essays are definitely futuristic in that they deal with phenomena and experimental work which are not yet beyond laboratory investigation, but which hold out promise for the future. The first speaks of mechanical testing of high polymers (rubber and plastics), and the second of the ageing and precipitation in metals. The last essay is on paramagnetic resonance—a subject which promises well but is still mostly experimental.

It is pleasing to note that mathematics have been kept somewhat in check, and more emphasis placed on the written word. There is a wealth of references to literature after all but one of the chapters. The book, like its predecessor, is most agreeably produced with matt paper providing easy reading without eyestrain. The editors, authors and publishers are to be complimented on this effort.

W. E. Schall

Principles of Mechanics of Solids and Fluids: Vol. 1. (Particle and Rigid-body Mechanics). *By Hsuan Yeh and Joel Abrams (McGraw Hill—69s. 6d.)*

This book is the first of two volumes on the mechanics of bodies. It is concerned with bodies which move but do not deform. Almost the entire book is founded upon the use of vector analysis, which is clearly explained in the opening chapter. This approach is admirable, as the simplicity of vector algebra has an immediate appeal to most students. Problems which are difficult by other methods can often be solved very easily by using vector notation.

In the second chapter Newton's three laws are introduced, and in subsequent chapters problems of statics and dynamics are solved using vector methods. The exception to this is the chapter on vibrations and the final chapter, which deals with Lagrange's method of solving dynamic problems in generalised co-ordinates.

As the authors point out in their preface and the introduction to the last chapter, with the types of problem which are presented to the engineer and scientist in this modern age, they cannot afford the luxury of ignoring the powerful vector and Lagrangian methods of analysis. This book is excellent because it introduces these methods with great clarity right at the outset, and it is therefore a very valuable tool for any teacher or student of dynamics. We look forward to Volume 2.

N. W. Murray

OTHER BOOKS RECEIVED

Abstracts of Theses 1960. *(Massachusetts Institute of Technology—$3.50.)*

Abstracts accepted during 1953-54 for Degree in various engineering branches.

Automation and Skill. *By E. R. F. W. Crossman. (D.S.I.R./H.M.S.O.—3s. 6d.)*

Results of research into economic, human and technical problems arising from advances in automation.

Symposium of Newer Metals. *(A.S.T.M. Technical Pubn. 272—$7.50.)*

Includes papers on refractory metals, nuclear and light metals, and processing of the newer metals such as niobium and tantalum.

1959 References on Fatigue. *(A.S.T.M. Stp. 9-K—$4.)*

Fatigue, an important consideration to any engineer, has been the subject of many articles and reports, and this book lists all published data on this subject, covering both the U.S.A. and Europe.

Factory Building Studies: No. 6 (Noise in Factories). *(H.M.S.O.—3s. 6d.)*

A survey of the main causes of noise in factories, and available methods of reduction and suppression.

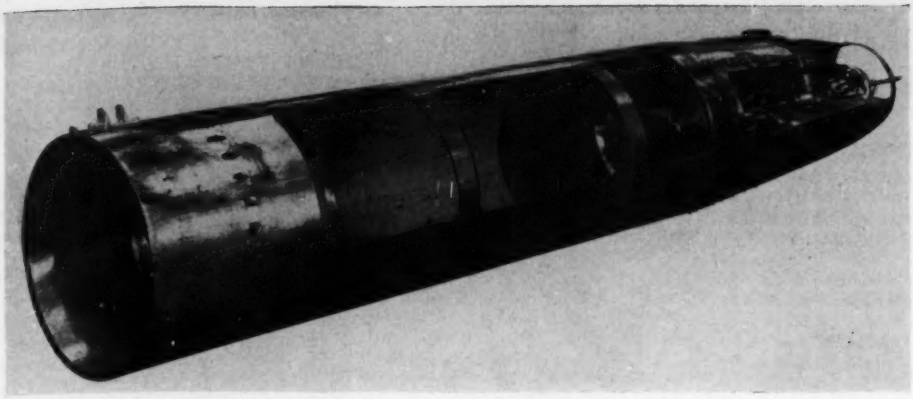
Symposium on Fatigue of Aircraft Structures. *(A.S.T.M. Technical Pubn. 274—$4.)*

These papers were originally presented at the 3rd Pacific Area National Meeting, held at San Francisco in October 1959.

BS 903: 1950. *Methods of Testing Vulcanised Rubber. (British Standards Institution—10s. 6d.)*

BS 3274: 1960. *Tubular Heat Exchangers for General Purposes. (British Standards Institution—£1.)*

BS 1442: 1960. *Galvanised Mild Steel Wire for Armouring Cables. (British Standards Institution—4s.)*



An early version of the Bristol Thor ramjet.

NEW DEVELOPMENTS WITH STAINLESS-STEEL

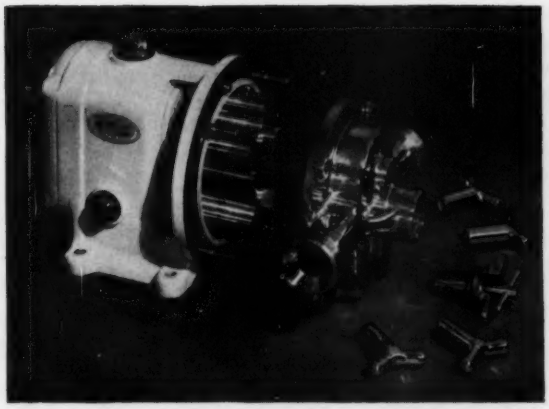
THE bulk of the stainless steels produced today are of the standard austenitic qualities, readily lending themselves to fabrication and welding. There is, however, an increasing tendency to demand steels with higher strengths to permit more sophisticated designs, with important effects thereby on the strength/weight ratio of products.

It is true that cold-worked austenitic steels will produce strengths up to 70 t.s.i., but such materials are difficult to fabricate and have found little use outside the railway and aircraft industries, where special arrangements have had to be made to deal with welding without loss of strength at the weld. A new approach to this problem in the last few years has been the development of semi-austenitic steels, which not only have good formability but can subsequently be hardened up to 80 t.s.i. tensile strength either by low-temperature distortion-free tempering, involving also some precipitation hardening, or alternatively by freezing at −70 deg. C., which has the advantage of being scale free. Subsequent tempering raises the proof stress to 50-60 t.s.i.

These precipitation-hardening stainless steels are somewhat expensive, however, and a cheaper range of variations of the martensitic 12 per cent chromium type cutlery steels now exists, having been developed to give strengths from 60-85 t.s.i. depending on the tempering temperature; this range allows of fabrication after normal quenching. These steels contain in addition some nickel, molybdenum and vanadium, and also sometimes niobium. These elements give good tempering resistance and an excellent combination of ductility and impact resistance. For example, Izod figures are high and 70 ft.-lb. have been obtained on 70 t.s.i. tensile steels. These steels also have excellent elevated temperature tensile properties, and so not surprisingly are being used for gas turbine structures and steam turbine blading. Variations of these steels containing 15 per cent chromium for better corrosion resistance are also now available.

Still more complex variations of these martensitic qualities, containing cobalt, give high resistance to creep deformation and rupture at temperatures up to 600 deg. C. These are now used, rather than the much more expensive high-nickel alloys, for many critical rotating parts in aircraft jet engines. One of these steels, for example, has an average rupture stress of 18 t.s.i. at 600 deg. C. in 300 hr., combined with a good level of creep ductility. These steels are also now available vacuum melted, with the object of greatly reducing solid oxides and other non-metallic inclusions, and thus improving the properties, especially the ductility.

The development of new austenitic creep-resisting steels is advancing with the technology of steam plant engineering, and to meet proposed steam temperatures over 595 deg. C.



Internal view of a Howard pump (Howard Pneumatic Engineering Co. Ltd.)

and pressures over 4,000 p.s.i. One of the first of such stations to go into service was Eddystone, in the U.S.A., using 18/12/3 chromium, nickel, molybdenum quality for the steam pipes, but a stronger steel than this, permitting a 50 per cent increase in design stresses, has recently been introduced in the U.K., based on 18/10/6 chromium nickel manganese. On the basis of the A.S.M.E. Boiler Codes, design stresses of 18,700 p.s.i. would be permissible at 600 deg. C. for extended service up to 100,000 hr. with this steel.

For nuclear use, a number of stainless steels are being produced containing 3-4 per cent boron, to act as shielding in view of the ability of boron to capture neutrons. Boronated stainless steel tends to be brittle, and is difficult both to make and to fabricate, but there is now ample confidence in the alloy. Vacuum-melted stainless steel may also be necessary to ensure maximum freedom from non-metallic inclusions for the thin-walled tubes that will be necessary to can the fuel in the more advanced gas-cooled reactor systems now under development.

One of the greatest benefits to stainless-steel users in the last few years has been the introduction of continuously rolled sheets, giving not only much improved surface finishes, but also availability of really thin sheets, for example, 0·012 in. thick. The use of carbide rolls for both sheets and narrow strip now permits a mirror finish without polishing on the 17 per cent chromium quality strip, used in such large quantities today for motor car trim.

Acknowledgment is made for this article to Samuel Fox & Co. Ltd. (Subsidiary of the United Steel Companies Ltd.).

SEEN AT THE

CORROSION & METAL FINISHING EXHIBITION

Non-wettable Chemicals

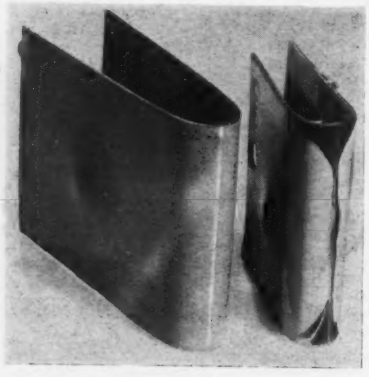
Hagafilm is a long-chain amine material used for preventing corrosion in condensate systems. The main constituent is octadecylamine, but there is a proportion of amines with shorter chain lengths which help to give protection over a wide range of conditions. It is a cream-coloured solid with a density less than that of water. Its melting point is 73·5-74·5 deg. C. and it is dispersed readily in hot water. This dispersion can be fed to steam or condensate lines or to boilers from which it distils with the steam.

By forming a non-wettable film, Hagafilm is claimed to control corrosion of process heaters, space heaters, evaporators and condensate lines. It is also said to improve heat transfer by keeping surfaces clean and by promoting dropwise condensation; many paper and board mills have reported an increase in output as a result of treatment. It can be used in plant on continuous load but is particularly useful where there is intermittent use, as protection is given during stand-by periods. Albright & Wilson (Mfg.) Ltd., 1 Knightsbridge Green, London, S.W.1.

EMD 5492 for further information

Cleaning and Phosphating

A process for simultaneously cleaning and phosphating is called Grisament. The left-hand panel shown here has been subjected to the process and demonstrates



enhanced paint adhesion. The right-hand panel has only been degreased prior to painting. Roto-Finish Ltd., 39 Park Street, London, W.1.

EMD 5493 for further information

Corrosion-proof Hose

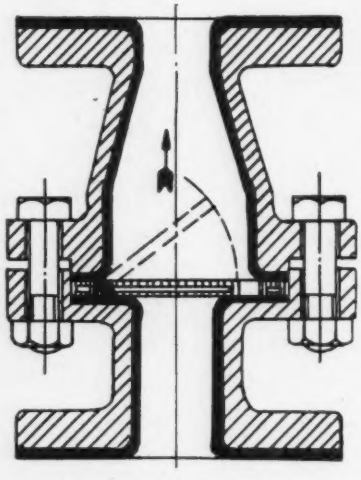
Precision extruded nylon hose and tubing are claimed to be the ideal media for carrying liquids where corrosion is likely to occur. Nylon tubing, both flexible and semi-rigid types TTF and TTR, were on show, as well as high-pressure nylon hose in sizes ¼-½ in. bore. Suitable end fittings for the tubing and hose are available, the fittings for the hose being re-usable. Tecalemit Ltd., Plymouth, Devon.

EMD 5494 for further information

Corrosion-resistant Valves

Type A diaphragm valve (size ¼ in.) has a body of solid p.t.f.e. The end connections are flanged to B.S.T.D., and are of gunmetal lined internally with p.t.f.e. and bolted to the body by stainless-steel tie bolts. The bonnet assembly is of cast iron coated with a suitable corrosion resistant plastics coating, and a baseplate of stainless steel is also coated in this manner. The body bonnet bolts are of stainless steel, the nuts being of brass. The diaphragm is Saunders 214 grade, which has a moulded p.t.f.e. facing. A ¼-in. valve is also available having solid p.t.f.e. hose end connections instead of flanges.

Type N non-return valve has been designed to meet persistent inquiries from the chemical industry for a valve of this type to withstand acid and other chemical



Type N, rubber-lined valve.

attack. The specification includes a cast-iron body, rubber lined with Saunders B grade rubber, and a flap of similar material. N-type valves are made in four sizes: 1, 1½, 2 and 3 in., with flanged connections to B.S.T.D. Saunders Valve Co. Ltd., Cwmbran, Monmouthshire.

EMD 5495 for further information

Corrosion Consultants

A complete service in the design and construction of acid-proof plant and vessel linings, floorings and protective coatings is offered for this country and overseas. Acid-proof design is the speciality of a technical department which claims wide experience in the design and construction of plant and structures subjected to chemical attack in acid, chemical and fertiliser manufacture, steel and non-ferrous metals pickling and trade effluent treatment. Corrosion Technical Services Ltd., Sunleys Island, Great West Road, Brentford, Middlesex.

EMD 5496 for further information

Plastics Fan

An innovation was a fan, designed and partially produced in Switzerland and completed in the U.K., with a moulded high-density polythene impeller and a pressed unplasticised p.v.c. case. The impeller, being light and resilient, is said to

be completely resistant to most acid and alkali fumes. Special features are stainless-steel securing belts and sockets, O-ring sealing, and a British-made and fitted motor and mild-steel frame. These fans are known by the trade name of Tough Colasit. Tough Plastics Ltd., Byfleet Road, Addlestone, Surrey.

EMD 5497 for further information

Epoxy Paints

Evokote Type 10 is a one-part Epikote resin-based paint specially suited for general maintenance painting of machinery, combining simplicity of application with rapid drying and good resistance to steam, heat, mild fatty acids, detergents and abrasion.

Evokote Type 20 is a two-part Epikote resin-based paint giving outstanding hardness and abrasion resistance. This material is supplied in the form of a clear lacquer and pigmented coatings. The clear lacquer has found considerable application on wooden floors, counter tops and laboratory benches.

Evokote Type 21 is also a two-part composition, and is claimed to possess outstanding resistance to water, steam and dilute fatty acids. This material has found particular application on bottle washing and filling machinery, chocolate mixers, wrapping equipment and conveyors.

The latest addition to the Evokote range of products is Evoscreed. This material is supplied in two grades known as G.P. and C.R. Both types consist of an Epikote resin-based medium into which is mixed selected aggregates and colours to produce a material which can be applied by trowel to any sound surface, and which will give an attractive and jointless floor. Evoscreed is said to have excellent resistance to water, acids, alkalis, fats, grease, oils, point loading and abrasion. Evode Ltd., Stafford.

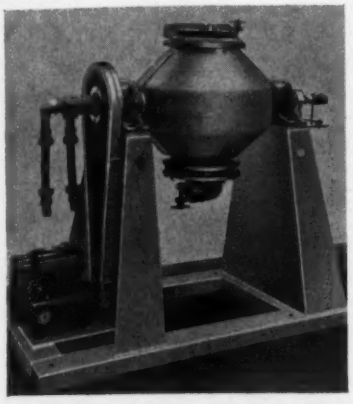
EMD 5498 for further information

SEEN AT THE

CORROSION & METAL FINISHING EXHIBITION

Glassed-steel Equipment

A glassed-steel dryer-blender was shown (see illustration), in which highly corrosive materials can be dried and blended to produce a homogeneous product with savings in operating time and costs. Drying is achieved by subjecting the product to vacuum and heat, and is speeded by a tumbling action which mixes the materials with an even thoroughness. The glass lining of the dryer obviates metallic contamination and resists product adherence, reducing clean-up losses and labour and improving heat transfer.



Also shown was a small British Pfaudler glassed-steel reaction vessel complete with agitator, which gives a much higher operating pressure than was possible in the earlier clamped-top models in this range. Further developments in the technique of fusing the glass lining to the steel are said to have produced a much improved lining which is highly resistant to all acids (except hydrofluoric acid) at all concentrations and at high temperature, and which is suitable for severe chemical service. The lining is also claimed to be resistant to alkali solutions up to a pH of 12 at 100 deg. C. Enamelled Metal Products Corporation (1933) Ltd., Artillery House, Artillery Row, London, S.W.1.

EMD 5499 for further information

Thermoplastic Polymer

The relatively new thermoplastic polymer, Penton, was shown in sheet, rod and tube form for fabricating purposes, and the exhibits illustrated its versatility in the powdered form for sinter coating, dispersion and solution spraying, and injection and extrusion moulding.

Penton is a chlorinated polyether of high molecular weight, linear in nature and crystalline in character. It is said to be extremely resistant to thermal degradation at processing temperatures, and to possess a unique combination of mechanical, electrical and chemical-resistant properties. It can be moulded with conventional equipment. Hercules Powder Co. Ltd., 1 Great Cumberland Place, London, W.1.

EMD 5500 for further information

Spot-welding Torch

A new prototype argon-arc spot-welding torch, the S.W. 300, which will supersede the present standard torch in 1961, is said to be simple to use and cheap to run. Access to only one side of a joint is required, and spot welds can be made with one hand and by semi-skilled labour. Shear values are claimed to compare favourably with those from resistance welding. Welding conditions are preset and the process is semi-automatic, so that only occasional changing and resetting of the tungsten electrode is required. A good surface finish is ensured, and little or no grinding and polishing is said to be needed.

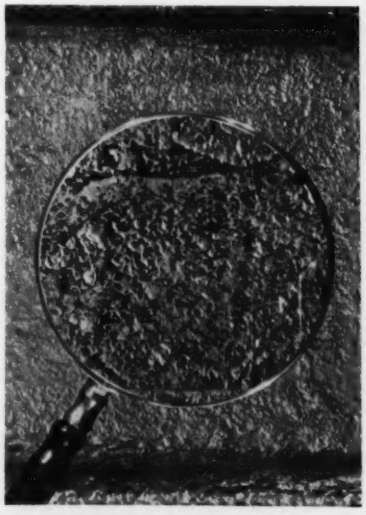
The torch is water-cooled and can carry currents up to 300 amp. It is switched on by a button-type micro-switch in the handle, and the back-entry collet enables the electrode to be replaced or adjusted simply and quickly, without removing the ceramic adaptor or argon shield. With interchangeable nozzles, the torch can be used for making spot welds in horizontal or vertical positions, on narrow flanges, or on 90 deg. outside corner joints.

The application of the argon-arc spot-welding process to stainless steel has recently received approval from the Aeronautical Inspection Directorate. In addition, recent development work indicates that the process can be used on commercially pure aluminium and on some aluminium alloys. Mild steel, steel alloys and titanium can also be joined by this method. The British Oxygen Co. Ltd., Bridgewater House, St. James's, London, S.W.1.

EMD 5501 for further information

Metal Preservative

A few years ago the discovery of ancient metal implements remarkably preserved by tannins in the soil surrounding them



suggested a method of halting corrosion which had already begun, and led to the development of Plus-Gas Formula E. This fluid combines with the oxides on corroded metals to form an insoluble tannate film which halts further corrosion by rendering the metal inert. At the same time it creates a smooth and burnished surface which bonds well with paints and increases their covering capacity. (The accompanying illustration shows the hard burnished surface produced by Plus Gas Formula E on a heavily corroded surface.) Furthermore, since Formula E is non-acid and non-toxic, it is claimed to be easier and safer to use (as well as being a good deal cheaper) than phosphate or phosphoric acid anti-corrosion compounds. The Plus-Gas Co., 1-11 Hay Hill, London, W.1.

EMD 5502 for further information

Fabrication in Plastics

This company specialises in the fabrication of chemical and corrosion-resisting plant, mainly tanks, vessels, pipe installations, fume extraction ducting and laboratory equipment, from corrosion-resisting plastics such as rigid p.v.c., polythene,

polypropylene and Fibre-Vinyl, which is a combination sheet of rigid p.v.c. and polyester glass fibre claimed to have excellent chemical and temperature resistance and impact strength. A.C. Plastic Industries Ltd., 1-3 Long Street, E.C.2.

EMD 5503 for further information

Cathodic Protection

A model of a steel jetty illustrated the application of cathodic protection for the prevention of corrosion to submerged piles. This model demonstrated the efficiency of the recently introduced platinised lead anodes for cathodic protection purposes. These particular anodes are said to have a virtually infinite life at current densities of 100 amp./sq. ft. in sea water.

The latest type of holiday detector for testing pipelines was also demonstrated in action on a section of coated pipe. This particular holiday detector has automatic visual and audible warnings to determine faults in the coating and wrapping of pipelines. Metal and Pipeline Endurance Ltd., Woolmer Green, Knebworth, Herts.

EMD 5504 for further information

CREEP AND RUPTURE PROPERTIES OF 2¼ PER CENT Cr, 1 PER CENT Mo STEEL

Engineering Materials and Design
DATA SHEET No. 52

By virtue of its alloy content, this steel is capable of appreciable air hardening, and the heat treatments given produce tensile strengths compatible with both fabrication and creep resistance requirements.

The tests relate to thirty-two heats of steel covered by the following composition range: C, 0·082–0·17; Mn, 0·038–0·69; Si, 0·13–0·38; Cr, 2·06–2·35; and Mo, 0·87–1·07 per cent.

Previously published creep behaviour of this steel was assessed on the basis of 1 per cent plastic strain, the tests extending to 14,000 hr. at 538 deg. C., 17,000 hr. at 565 deg. C., 12,000 hr. at 593 deg. C. and 11,500 hr. at 621 deg. C. On the basis of rupture the tests extended to 30,000 hr. at 538 deg. C., 32,000 hr. at 565 deg. C., 33,000 hr. at 593 deg. C., 25,000 hr. at 621 deg. C. and 7,000 hr. at 650 deg. C.

Extrapolation

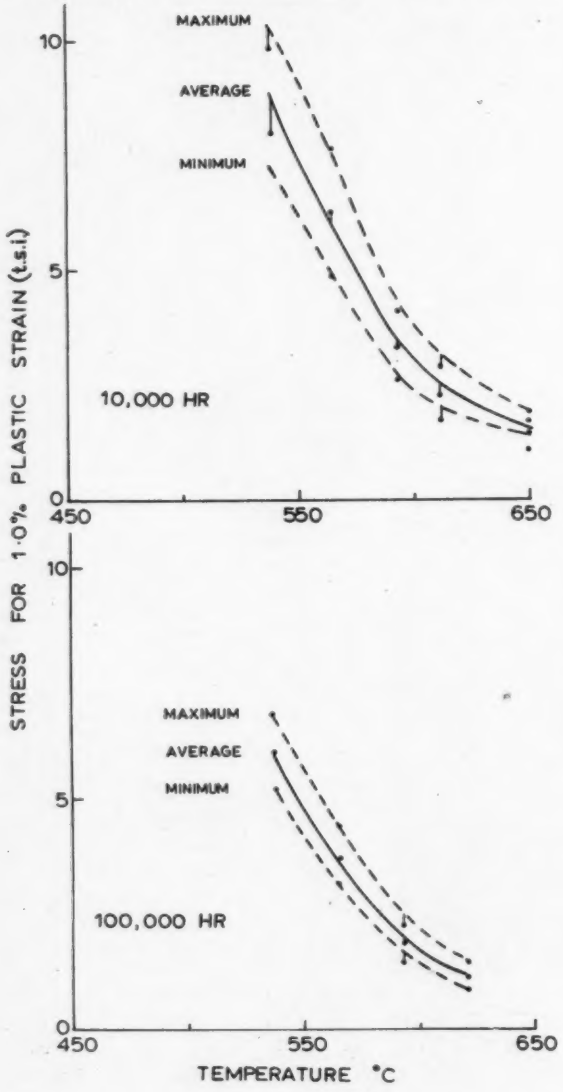
Assessments of the stress to give rupture at 100,000 hr. were extrapolated. With more long-time data becoming available, it is becoming increasingly obvious that the relationship between log stress and log time to rupture is not linear, but with log stress as ordinate it assumes a downward curvature. This feature has been taken into account in the extrapolations.

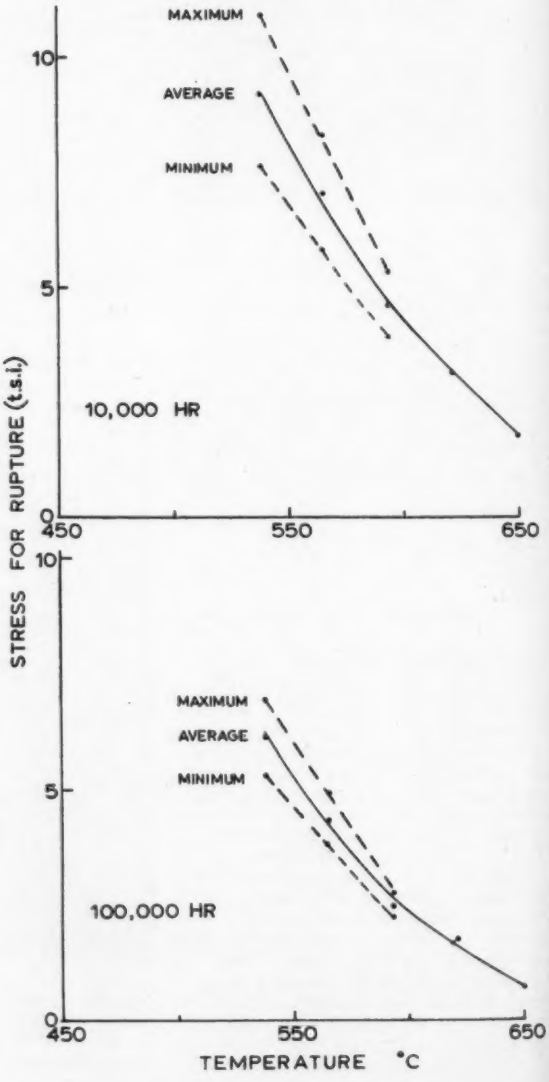
In constructing the scatter band, account was taken of the fact that the degree of scatter decreases with an increase in the test duration. The evidence that the degree of scatter decreases with test duration was obtained from other laboratory work.

KEY TO SYMBOLS USED

- ○ Anneal at 930°C.
- ▽ Normalise at 898°C., temper at 734°C. for ½ hr.
- ◇ Normalise at 989°C., temper at 734°C. for ½ hr.
- × Anneal at 930°C.
- \+ Control anneal at 960°C., cool at 400°C./hr., temper at 690°C.
- □ Anneal at 930°C.
- ● Anneal at 930°C.

Data by J. D. Murray, A. Met., A.I.M., of the Research and Development Department, United Steel Companies Ltd.





The design data given can be taken as general for this composition, irrespective of the various heat treatments that have been given. The heat treatments that were employed, and which are recommended for this steel, are as follows:

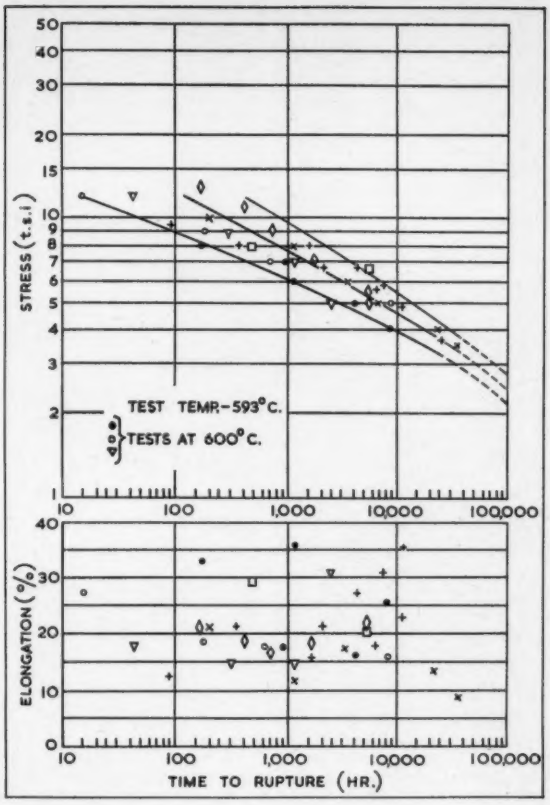
(a) Full anneal, preferably with a cooling rate of between 15 and 60 deg. C. per hr. through the temperature range 930–650 deg. C. After this treatment, tempering is not necessary other than for stress-relieving purposes, in which case it should not exceed 700 deg. C.

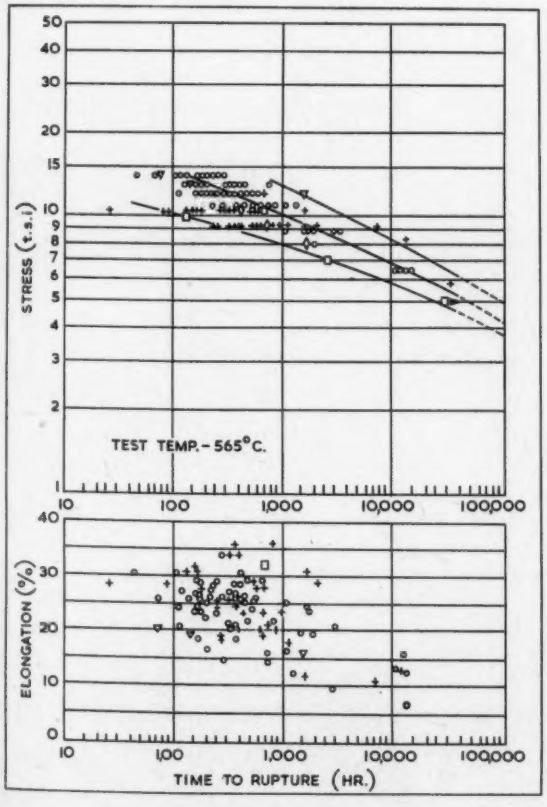
(b) Control anneal and temper, cool at 400 deg. C. per hr., followed by tempering in the range 650–690 deg. C.

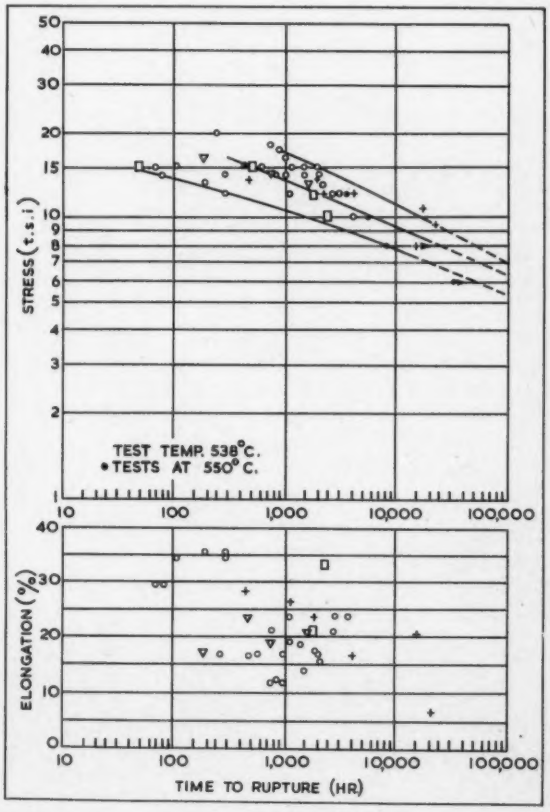
(c) Normalised tempered-cool in still air, and temper in the range 650–750 deg. C. In this case it is important that the tempering treatment is not too severe, such that it reduces the tensile strength below 36 t.s.i.

The values obtained from the extrapolated curves are as follows:

1·0% PLASTIC STRAIN						
Temp. (°C.)	Stress (t.s.i.)					
	10,000 hr.			100,000 hr.		
	Max.	Min.	Average	Max.	Min.	Average
525	—	—	10·1	—	—	6·9
550	9·1	6·2	7·5	5·7	5·2	4·7
575	6·1	4·0	5·0	3·4	2·4	2·9
600	3·8	2·4	3·1	2·0	1·4	1·7
625	2·5	1·7	2·1	1·2	0·8	1·0
650	1·8	1·4	1·6	—	—	—
RUPTURE						
525	—	—	10·3	—	—	7·0
550	9·7	6·7	8·2	6·0	4·6	5·3
575	7·0	5·0	6·0	4·0	3·2	3·6
600	4·8	3·6	4·2	2·6	2·0	2·3
625	—	—	2·9	—	—	1·4
650	—	—	1·7	—	—	0·7







EMD 5414 for further information

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SOLUTIONS FOR THIN-WALLED TUBES

Engineering Materials and Design
DATA SHEET No. 52

Section Modulus

This nomogram gives solutions for section modulus for thin-walled tubes, using scales 1, 2 and 3. Approximate limitations for use (i.e., maximum thickness for a given radius dimension) are indicated on the right-hand side of scale 1. Where the appropriate value of T exceeds the limit shown, the standard formula should be used, i.e.:

$$\text{section modulus} = \frac{\pi(R_1^4 - R_2^4)}{4R_1}$$

Moment of Inertia

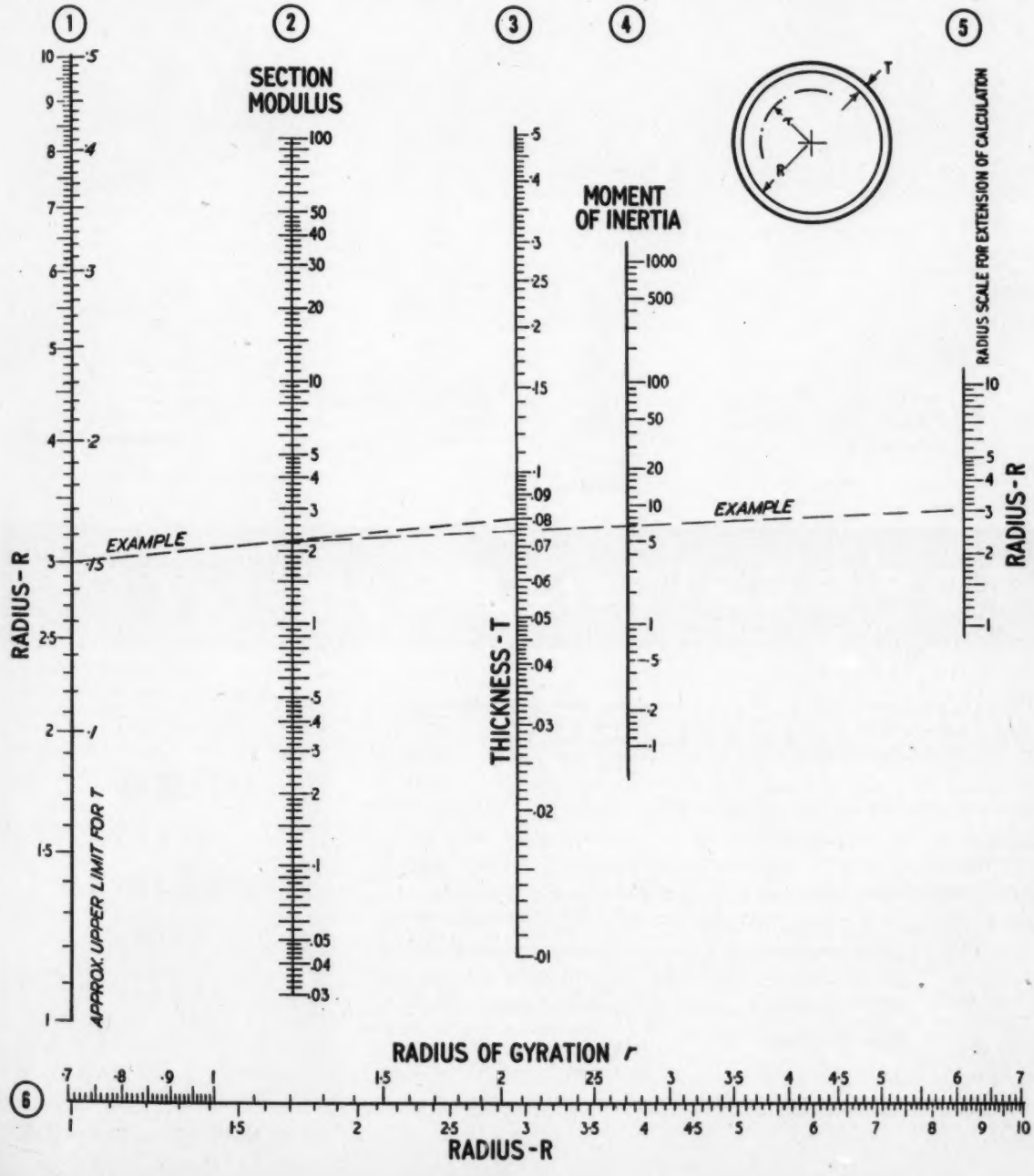
Solutions can be extended to find the equivalent moment of inertia by connecting the section modulus value (scale 2) to the extreme right radius) scale 5, and reading the answer on the moment of inertia scale 4.

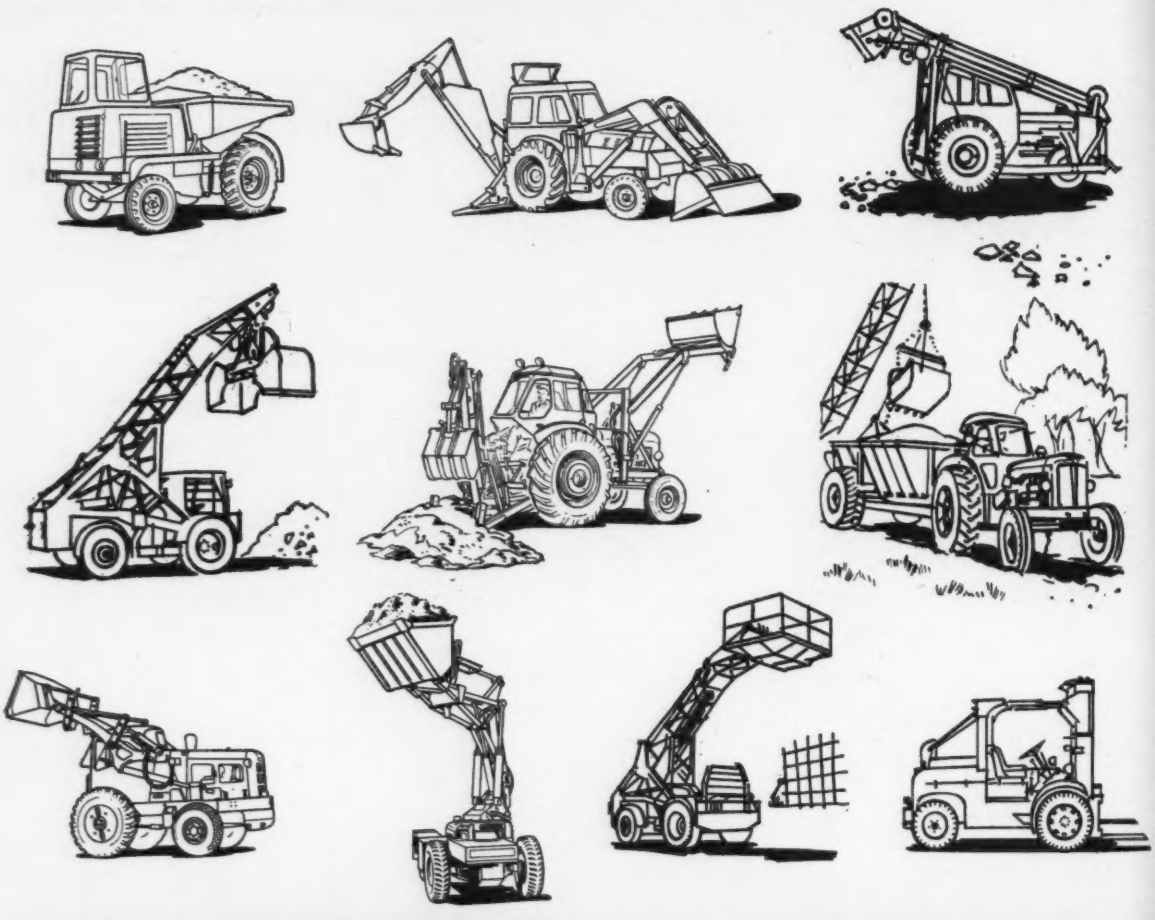
Radius of Gyration

Radius of gyration may be read directly from the bottom horizontal scale 6, for any value of radius R. Again this only applies within the thickness limit as for section modulus. Outside this limit, radius of gyration must be calculated from the standard formula, viz.:

$$\text{radius of gyration} = \sqrt{\frac{R_1^2 + R_2^2}{4}}$$

Example. Section modulus for 3-in. (inner) radius tube with a wall thickness of 0·08 in. derived from first three scales = 2·26. Extend to scale 5 to determine moment of inertia of section = 6·8 (on scale 4).





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WHAT'S NEW IN MATERIALS & COMPONENTS

Non-corrosive Cleaning Solvent

Chlorothene Nu, a specially inhibited form of 1,1,1-trichloroethane, is a cleaning solvent which is said to be non-corrosive, economical, powerful enough to remove oil, greases and waxes, and to dry fast without leaving residue. It is suitable for wipe, dip, spray and slush cleaning applications, and is claimed to have safety qualities of low inflammability and low toxicity. Its special inhibitors are said to make it virtually non-corrosive to metals, and it can be used to clean a wide range of articles. (The illustration shows Chlorothene Nu being used for removing grease from the windings of a large electric motor. Penetone-Paripan Ltd., P.O. Box 10, Egham, Surrey.

EMD 5505 for further information

Dual-purpose Dyeline Paper

Ammosheen, the latest addition to the Admel Ammo range of dyeline materials for ammonia gas development, is a dual-purpose printing paper. Its combination of beauty and toughness is said to make it the ideal material for workshop drawings and display prints. It is a diazotype sensitisation on an aluminised plastics-coated card-weight paper. The waterproof plastics surface on both sides of the print makes it the ideal material for workshop drawings. Grease marks and stains are claimed to be easily removed with a damp cloth, and the durable card-weight paper stands a considerable amount of rough handling.

Ammosheen reproduces lines, solids and screen half-tones, yielding a glossy blue image with all the density of printer's ink, on a dramatic silvery background. For short-run production of signs, posters and display material, it offers the user an interesting and dramatic medium which is said to be more economical than letterpress, lithography or silk screen. Lawes Rabjohns Ltd., Abbey House, Victoria Street, London, S.W.1.

EMD 5506 for further information

Self-adhesive Envelope

Carbion consists of a strawpaper or similar suitable base processed on special machines which give it a permanent double-wave pattern. The pattern flattens under load, but regains its shape when the load is removed, making the material resilient and giving it considerable cushioning properties. Already used as an interlining, case lining and general cushion-packaging material, its applications have been considerably extended by coating it on one side with latex solution. Folded back on itself, the touching sides immediately form a bond which, while firm, can be neatly parted by pulling the sides apart.

Parts to be protected are simply placed on a piece of self-adhesive Carbion of appropriate size, which is then folded back on to itself. After pressing down along the edges and around the contained parts, these are immediately securely held in an "envelope" which at the same time provides cushioning protection. To remove the parts the envelope can be torn open, or the seal can be opened by simply pulling the edges apart, in which case the same piece of material can be used more than once. Spicers Ltd., Loughton, Essex.

EMD 5507 for further information

Worm Gear Oil

A synthetic lubricant which is claimed to have a coefficient of friction comparable with that of castor oil, and similar load-carrying capacity, but without its disadvantages, has been made generally available after extensive trials. Known as Dentax W, the oil contains a special inhibitor which is claimed to eliminate oxidation and permit up to three or four times the normal mileage before the oil need be changed. It is said to be stable and non-reactive, and contamination with conventional mineral oils is therefore not disastrous. The new oil is intended for use on the worm drives of heavy vehicles, and it is believed that the increased cost of the oil is more than offset by the increased mileage obtained. Shell-Mex & B.P. Ltd., Consumer Trade Dept., Shell-Mex House, Strand, London, W.C.2.

EMD 5508 for further information

Fire-retardant Paint

An emulsion-like paint called Albisaf No. 1 dries to a smooth, matt, decorative finish which, when exposed to fire or heat, swells rapidly, resulting in a thick, stable, foam-like layer with a high degree of thermal insulation. It is claimed to provide an effective barrier to the spread of flame on combustible surfaces, and also to reduce the likelihood of rapid distortion of metalwork due to heat. It is said to stop flame at its point of contact, and to reduce the volume of toxic gases normally produced by the combustion of timber, plywood, wood fibreboards, insulation boards, etc.

Tests by the Joint Fire Research Organisation have placed surfaces treated with Albisaf No. 1 in Class 1 according to BS 476: 1953, thus fulfilling the requirements of the Thermal Insulation (Industrial Buildings) Act, 1957.

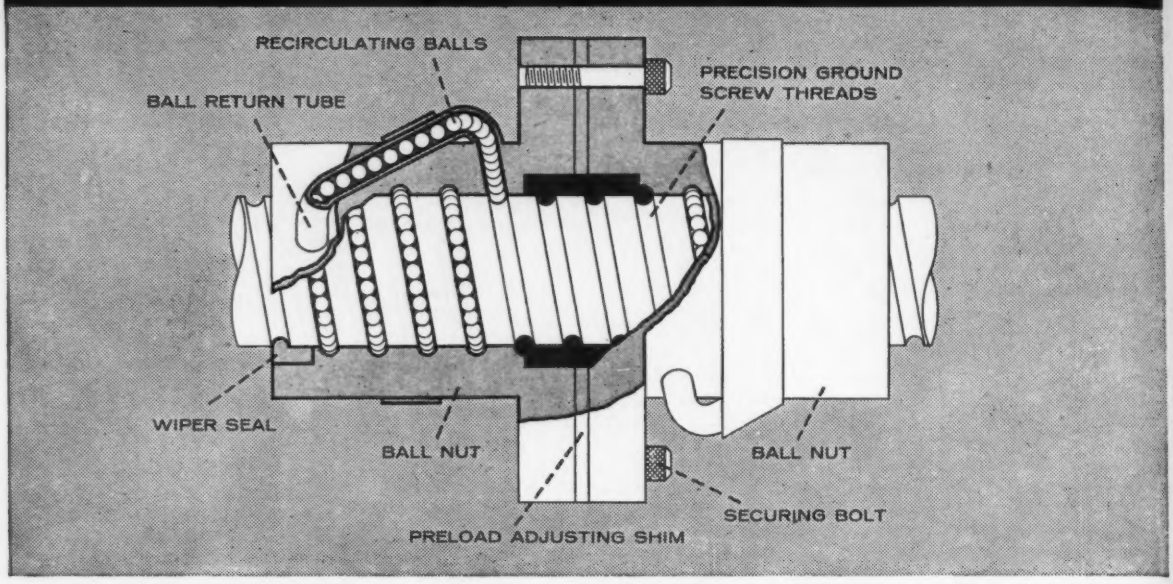
The paint may be applied directly to wood fibreboards, timber, plywood and primed metals, and also may be safely applied over shop-primed joinery. It is claimed to retain its fire-retardant properties throughout the whole of its decorative life, and with normal ventilation during application to provide no toxic hazards. Hadfields (Merton) Ltd., Mitcham, Surrey.

EMD 5509 for further information

FOR MORE INFORMATION
about any of the products mentioned on these pages, please use the special reply card bound in this issue.

READERS' ADVISORY SERVICE
We shall be pleased to help readers who have difficulty in tracing sources of supply of materials or components.

Beaver pre-loaded ball screws, up to 95% efficient, operate at -52°C to over 400°C with no backlash...



...ANOTHER ENGINEERING ADVANCE FROM BRISTOL SIDDELEY

Bristol Siddeley Engines Limited produce Beaver* pre-loaded ball screws. These ball screws achieve a minimum efficiency of 90% and they can operate within a temperature range of −52° C to 400° C without lubrication, and up to 170° C when lubricated.

Machined and ground to the highest standards of precision engineering Beaver pre-loaded ball screws greatly increase transmission efficiency. They reduce the power required for actuation by as much as 80%, when converting rotary drive into linear output or force input into torque output. By eliminating backlash, with pre-loading, they give precise control over very small increments of motion and a high response frequency. And when compared to conventional screw mechanisms, they provide a predictable operating life which is much longer, require much less maintenance and give more trouble-free operation.

Basic design application analysis

Bristol Siddeley engineers make an exhaustive analysis of each specification. And each unit is specially designed for its particular application. Beaver ball screws are made automatically reversible or with controlled "no-back," with multiple or single circuits. Beaver pre-loaded ball screws have been proved as the most efficient method of converting rotary into linear thrust in over 2,700 engineering applications in many branches of industry. They have been designed already with rated operating load capacities of 370,000 lb (825,000 lb maximum static load) but the maximum potential operating load is, in most cases, limited only by the requirement.

Bristol Siddeley Beaver ball splines have been developed to eliminate the disadvantages of conventional splines. The designs are very effective in minimising friction, particularly when high torsional and bending loads are imposed during linear movement.

** Complete technical and manufacturing co-operation with Beaver Precision Products Inc., Detroit.*

For further information please write to J.B. Starky, Sales Manager (Ball Screws and Splines), Bristol Siddeley Engines Limited, PO Box 17, Coventry, England.

BRISTOL SIDDELEY ENGINES LIMITED

Metallised Plastics Film

Mirro-Brite Mylar consists of metallised Mylar film laminated to a variety of materials, which include unsupported vinyls in various thicknesses, vinyl coated fabrics, and even latex-impregnated papers. It is available in any one of twenty-six embossed patterns, or plain (unembossed), with a choice of six colours, and with or without pressure-sensitive adhesive backing in the case of unsupported vinyls. Mylar itself is said to be one of the strongest plastics films known. It is chemically inert, will not grow brittle, and will withstand a wide range of temperatures (i.e., 60-150 deg. C.).

When laminated to vinyls and other materials, the layer of metal is trapped between the layer of Mylar and the laminate. In this fashion durability is ensured, owing to the protection of the metal plating.

Chrome (silver) colour consists of a layer of Mylar, a layer of metal and the laminate. Gold or other colours consist of a layer of specially dyed Mylar plus the metal and laminate—this ensures greater flexibility of material and, most important, colour fastness, durability and consistency. Bardens (Bury) Ltd., Hollins Vale Mills, Bury, Lancs.

EMD 5510 for further information

Non-woven Fabrics

In the field of reinforced plastics, Lantor non-woven fabrics are claimed to offer economic advantages over woven fabrics, together with technical advantages which include a high level of fatigue resistance, impact strength and machinability. The two main applications for non-woven fabrics in the field of high-pressure laminates are their use in sheet form, and as gear shapes. With low-pressure laminates, the fabrics have wide application as surfacing tissues for polyester-resin-glass laminates for various uses in chemical plant, or for factory windows. The use of a non-woven outer skin for such laminates is said to improve the weathering qualities of the laminate, and give a high resistance to degradation. Non-woven fabrics used for this purpose are made of synthetic fibres which are specially compounded to be compatible with the polyester resins and the binders used in the laminate.

Non-wovens can also be used in the field of filtration, for both air and liquid uses. Filters made from non-woven cotton bonded with synthetic rubber are said to give a lower back pressure than woven fabric filters, thus reducing the power necessary to obtain effective filtration.

Woven fabrics are at present much used for electrical insulation, particularly for cable wrapping. Non-woven fabrics have been found to be equally effective for this purpose, offering an economy in comparison with woven fabrics. They are also claimed to have a wide range of uses in the field of high-frequency welding. Fothergill & Harvey Ltd., Harvester House, Peter Street, Manchester, 2.

EMD 5511 for further information

P.v.c. Coatings

An entirely new p.v.c. finishing coating material, in three grades that permit spray-brushing, stoving and air drying, is claimed to adhere strongly to wood, brick, concrete, asbestos and all metals.

The p.v.c. spray-stoving system (MS/HC) has been developed to meet the demands for finishes superior to normal stove-enamelling but with similar coating thicknesses. It is possible to apply it to large or small articles, in any desired film thickness from 0·0025 in. and upwards. The coating gives a hard, glossy, smooth surface with a vitreous-like finish and warm plastic feel.

The p.v.c. spray-brush air drying system (MS/AD) is designed to include articles that cannot be processed by the stoving system. It can be applied to wood, concrete, brick, asbestos and ferrous and non-ferrous metal surfaces. This material is said to have the same protective and other properties as the stoving system, including thicknesses of coating. The surface finish, however, is an eggshell gloss.

The p.v.c. air drying system (MM/AD) is a really tough coating with an extremely high resistance to acids and chemicals, at the same time having all the properties of the MS/HC and A/D systems. The finish has a slight orange-peel appearance, and is said to be tough yet resilient, with excellent adhesion. Plasinter Co. Ltd., Holyhead Road, Wednesbury.

EMD 5512 for further information

Bonded Surface Coating

A new development in the fight against corrosion is called Isokote, and is based on isophthalic polyesters and specially woven fabric reinforcements of glass, Terylene or other suitable fibres. These coatings are applied in successive layers by spraying and other methods, until the required thickness is built up. Among the many applications is patching of leaking tanks, and the provision of linings for corroded

or new vessels which arrest and prevent chemical attack.

A special advantage claimed for the application of Isokote is that it can be applied *in situ*; therefore, downtime is greatly reduced and dismantling and removal costs eliminated.

All types of tanks and hoppers carrying water, sand, coal and effluent have been lined with Isokote; also, the roof, valleys and gutters of a London film theatre have been completely coated for protection against the highly corrosive atmosphere. Extrudex Ltd., Western Road, Bracknell, Berks.

EMD 5513 for further information

Quartz-filled Plastics

Durez 19387 is a quartz fibre-filled two-stage phenolic material, designed to provide minimum erosion on exposure to high velocity gas streams at 1,650-3,300 deg. C. Moulded parts provide excellent thermal insulation. It is recommended as a material for rocket motor liners, blast tubes and nozzles. Omni (London) Ltd., 35 Dover Street, London, W.1.

EMD 5514 for further information

Lantor non-woven fabric being applied as a surfacing cloth for a plastics car top.

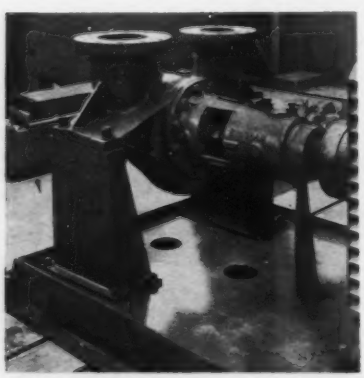
Safety Switch uses Permanent Magnet

The Mobrey magnetic safety switch comprises a dust- and hose-proof switch enclosure in diecast aluminium, the cover of which is held on by four lock shield screws—these can only be removed by use of the key provided. The switch is of the single-pole changeover air-break type, normally with silver moving and carbon fixed contacts. It is suitable for a.c. supply only up to 440 V. Maximum load is 1·0 amp. Particularly suitable for fitting to the safety guards of electrically driven machines, when wired in series with the operating coil of the contactor starter, it causes the machine to stop when the guard is opened. Ronald Trist & Co. Ltd., Bath Road, Slough.

EMD 5515 for further information

Balanced Pressure Centrifugal Pumps

A range of centrifugal pumps to the design of The Bingham Pump Co. of Portland, Oregon, U.S.A., is now being manufactured. The main feature of these pumps is that they are of double volute construction, and it is claimed that this makes possible the elimination of the troubles due to hydraulic unbalance commonly associated with the single volute type of pump. It is said that in the twin volute pump there are no unbalanced forces to cause wear or seizure between rotating and stationary parts. This is achieved by making the double volute pump case in the form of two exactly similar volutes, each spanning half of the impellor circumferences. At any two points on opposite sides of the impeller, the shape and area of the adjacent casing and the



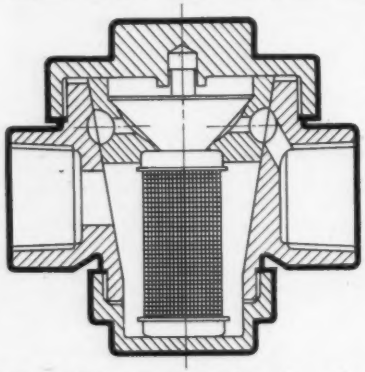
velocity of flow therein are respectively equal. By virtue of this design, it is claimed that hydraulic pressure, acting radially against the impeller at any point, is balanced by an exactly equal pressure acting against the opposite side of the impeller—regardless of head, capacity or speed at which the pump is operating. The range of pumps available includes versions for corrosive chemical or petroleum liquids. David Brown Ltd. (Foundries Division), Penistone, Nr. Sheffield.

EMD 5516 for further information

New Steam Trap

The Mil TherMatic is a simplified steam trap which has been specifically designed to meet the needs of modern plant, with special emphasis on its ability to discharge condensate at steam temperature consistently, from no load to maximum. Six components form a complete trap strainer unit, with only one moving part. The internal trim is of high-grade stainless steel, and the choice of body materials includes manganese bronze forgings or stainless steel castings. No gaskets are used in the assembly.

The basic principle upon which the trap operates depends on a well-known principle of physics. The valve is held on its seat by the conversion of the kinetic energy of flashing condensate into pressure energy. When this pressure is



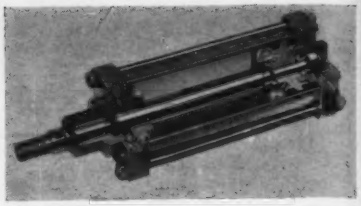
destroyed by recondensation, the valve opens to discharge the condensate from the equipment being drained. The trap is suitable for a wide range of applications from 5-250 p.s.i. with a manganese bronze body, or 5-400 p.s.i. with a stainless-steel body. Sizes available are ½ and ¾ in. screwed B.S.P.T. or A.N.P.T. connections. Midland Industries Ltd., Heath Town Works, Wolverhampton.

EMD 5517 for further information

Square End Air Cylinders

A new range of air cylinders having the square end and tie-bolt system of construction has been introduced by Schrader. The new square end design means that the cylinders can easily be fitted with interchangeable mountings. In this way a basic cylinder can be used for neck, leg, front or rear trunnion, and front or rear plate mountings. The cylinders can be supplied cushioned or non-cushioned.

The cylinders are available in bore sizes from 1½-4 in., and can be operated on pressures of 5-150 p.s.i.g. The piston rods, which are of ground steel, are avail-



able in standard strokes of 4-12 in. cushioned and 1-12 in. non-cushioned. The end plates are of forged brass, and the tie rod assembly ensures perfect location with the heavy brass tubing. The tie rods also form the fixing points for all mountings attached to the end plates. Synthetic rubber seals are provided to ensure positive sealing and constant cushioning. A. Schrader's Son, 829 Tyburn Road, Birmingham, 24.

EMD 5518 for further information

Continuous Integrator

For providing an integral of any variable, measured on an electronic strip chart recorder, a continuous integrator has been introduced. The total area under the curve is presented as a permanent record on the left of the chart as the curve appears; a pen marks each count on one side of a line, and every tenth count on the other side. Any area can thus be easily evaluated. Simultaneously, the integral is shown on a four-digit counter. The continuous integrator is fitted beneath, or near, a Honeywell ElectroniK strip chart recorder, and is used in applications requiring measurement of a quantity over a period, as well as instantaneous values. Typical applications include gas chromatography, flow, electrolytic cell current, electric power, power consumption in an electricity network, continuous weighing and current measurements to determine the efficiency of aluminium pot lines.

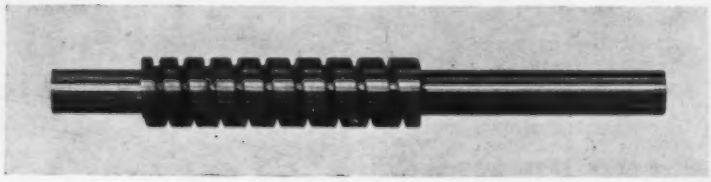
The output of the integrator can take the form of a d.c. pulse for feeding to data handling apparatus or remote counting equipment. A four-gear speed-change device in the recorder provides different chart speeds to suit low or high count rate. Accuracy of integration is claimed to be within 0·5 per cent of full-scale area for integration between 5 and 100 per cent, this accuracy being maintained through supply voltage changes of ±10 per cent. The accuracy of the recorder remains unaffected at ±10 microvolts on the 1-mV. span. Honeywell Controls Ltd., Ruislip Road East, Greenford, Middlesex.

EMD 5519 for further information

Variable Pitch Screws

Variable pitch traverse screws in small or large numbers can now be made to special order, as the result of the development of a special machine for this purpose by Johnson Precision Instruments Ltd., Huntingdon Street, Nottingham.

EMD 5520 for further information



Hydraulic Deceleration Valve

The deceleration of moving machine or mechanical parts can present a number of problems to the designer of hydraulically-operated devices. Although the exhaust flow from an actuator may be diverted so that it can only escape back to the hydraulic reservoir by blowing over a relief valve, this system of dynamic braking imposes a practically instantaneous predetermined constant pressure which applies a practically constant braking force. If, however, the mass to be decelerated varies from operation to operation, as might the load on a planer table with different jobs being undertaken, the differing braking distances could affect the reversal control on the table.

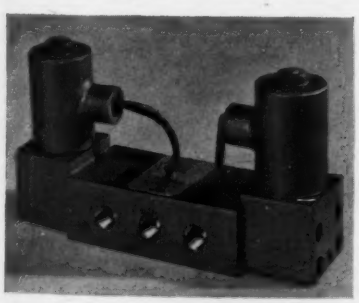
The Stein Atkinson Vickers adjustable deceleration valve uses a throttling principle, a pressure gradient being built up across the choke so as to permit the flow to continue. The more restrictive this choke becomes, the greater will be the pressure gradient across it, to maintain the same flow rate. The pressure gradient across the choke is used to provide the back pressure which will give the necessary braking force, and by controlling a variable choke the motion of the body being brought to rest is controllable.

Because the deceleration characteristics are determined by the profile of a cam, it follows that varying deceleration rates can be introduced, and also that intermediate deceleration and acceleration can be applied during the movement of the mass under control. The new valve has been designed to give optimum performance from 4-50 gal./min. up to 3,000 p.s.i. Stein Atkinson Vickers Hydraulics Ltd., 197 Knightsbridge, London, S.W.7.

EMD 5521 for further information

Double Solenoid Valve

The P.805 Red Ring Pilot-operated double solenoid valve for the control of pneumatic circuits is claimed to be particularly suitable for use in control cubicles and similar conditions. The valve gives instantaneous response with a very small current consumption. It is a five-port valve with piped exhaust, and is of



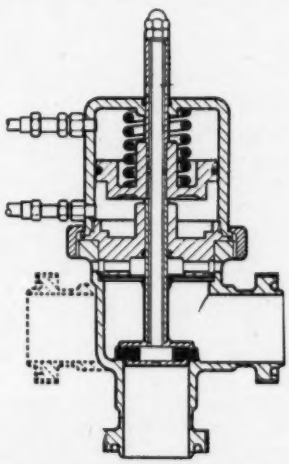
compact construction, the ¼-in. B.S.P. model having an overall length of 6¼in. The valve is available to suit all voltages, and in two models, P.805 for ¼ in. B.S.P. and P.905 for ½ in. B.S.P. Stuart Davis Ltd, P.O. Box 21, Stonebridge Highway, Willenhall, Coventry.

EMD 5522 for further information

Pneumatic Valve

The Zephyr air-operated valve has been developed to permit easy application of automatic and remote control, and is intended for circuit selection during processing or in-place cleaning in the dairy, food and beverage industries.

The on-off valve comprises two main assemblies, the head or air cylinder and the valve body. The change-over valve consists of identical head and valve body assemblies with a branch unit mounted between them to provide a third port. The method of joining the individual assemblies together avoids crevices, and makes it possible to clean the valve by circulating cleaning fluids through it whilst it is in place. Air connections are provided both above and below the piston, which permits air operation in either direction or, alternatively, a spring may be fitted to return the valve auto-

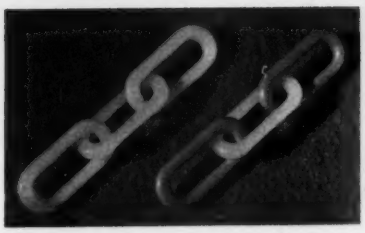


matically to an open or a closed position. When spring return is employed and the product pressure opposes the spring force, the valve will close against pressures of between 30 and 55 p.s.i. according to the size of the valve. The protruding end of the valve spindle permits a visual indication of the valve head position, and can, if required, be used to operate a switching unit. The valve is made from molybdenum bearing stainless steel, and is of hygienic construction. Type R.J.T., American 3 or German connections in 1½-, 2-, 2½- and 3-in. sizes are available. The A.P.V. Co. Ltd., Manor Royal, Crawley, Sussex.

EMD 5523 for further information

Nylon Chain

Wepla nylon chain, at present imported from Germany, is now available in this country. Only one-seventh the weight of iron chain of the same size, nylon chain is non-magnetic, noiseless and has low heat conductivity. Although it does not have the tensile strength of iron chain, it is nevertheless very strong, having weldless links with reinforced ends. These chains, which are available in any colour, or multi-coloured, would appear to have applications in the following fields:



Safety chains for the chemical industry; cordon or barrier chains in red and white; ships' rails; bracing chains for aerials used by the Services; agricultural chains; pulley chains; chains for supporting hose in large petrol refinery tanks; and, being hygienic, in food manufacturing plant and machinery. The chains are at present available in the 6 mm. dia. size, but 4-, 8- and 10-mm. sizes are to be produced at some future date. Schofield & Brown Ltd., 26 St. John's Road, Hove, 3, Sussex.

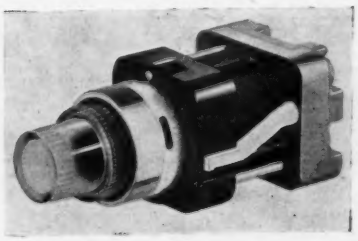
EMD 5524 for further information

Illuminated Push Button

Class 9001 Type TF is an illuminated push-button which combines the functions of a double circuit push-button switch and transformer-type pilot light in one compact unit.

The pilot light lens, when depressed, operates the contacts of a single-pole double-throw contact block. The illumination circuit is separate from the push-button circuit. This makes it possible for the light to be "on" whilst the lens is depressed only, or alternatively to remain "on" after the lens has been depressed and released, according to the external wiring arrangement. Pilot light lenses are available in a range of colours. Illumination is provided by a 6-8-volt miniature bayonet lamp operated from a transformer.

The unit, incorporating transformer, is available for supply voltages ranging from 110 to 600 V. at frequencies varying be-



tween 25 and 60 c/s. It is easily included into any Square D Class 9001 heavy-duty oil-tight control station. A lens guard can be supplied if required. Square D Ltd., Cheney Manor, Swindon, Wilts.

EMD 5525 for further information

Please Note!

We receive many reader enquiry cards on which the reader has omitted to fill in his name and address. In order to avoid disappointment we remind readers that names and addresses should be included on *each* card.

EMD 5418 for further information

THIS IS NOTHING TO WHAT GOES ON INSIDE A BULLOWS NOPUMP SPRAY BOOTH

ALMOST ENTIRELY ELIMINATES MAINTENANCE

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In this new type of Water-Wash Spray Booth the exhaust air travels at very high velocity over the water surface entraining water. The air/water mixture, moving through controlled changes of direction, provides the scrubbing action.

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STRETFORD · MANCHESTER

This Booth was started up on production on 1st March, 1959, and has operated two nine-hour shifts on continuous painting of agricultural machinery. When last examined, there was an average depth of silt of 6 inches over the entire water tank bottom, an area of 290 sq. feet. A further 4 inches, making 10 inches in all, can be accommodated before cleaning is essential. After 1 year's operation, the fan and ducting were barely discoloured, the only maintenance cost being cleaning the floor inside the booth, routine greasing of bearings and similar preventive maintenance.

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BULLOWS (AUST) PTY. LTD., ETHEL AVENUE, BROOKVALE, SYDNEY, AUSTRALIA

Document Rail

The Pano rail is a suspension rail of light weight made of aluminium and plastic, and obtainable in lengths of 48 in. It makes a suitable holder for sheet maps or drawings, the material simply being slid under the transparent clamping strip. If desired, mounted maps and illustrations can be hung from the hooks provided, which can be clipped along the top edge of the rail. Wood screws are also provided, and slotted holes are already made at the rear of the rail for temporary or permanent fixing.

The rail is not only simple to use, but it has the advantage of not damaging the charts, sheet maps, drawings, etc., being displayed; nor is the wall itself damaged by having to use drawing pins or adhesives. George Philip & Son Ltd., 30-32 Fleet Street, London, E.C.4.

EMD 5526 for further information

Dyeline Reproduction Machine

The Admel Revolute Rockette dyeline reproduction machine has a 42-in. feed width, and is available as a table-top unit or on its own stand. It is of robust construction, and employs a 1½-kW quartz lamp which is claimed to be very economical for this class of machine. Another feature of the Rockette is that the distance of travel of the original and exposed material is so short that a high rate of photoprint production is obtained. Lawes Rabjohns Ltd., Abbey House, Victoria Street, Westminster, London, S.W.1.

EMD 5527 for further information

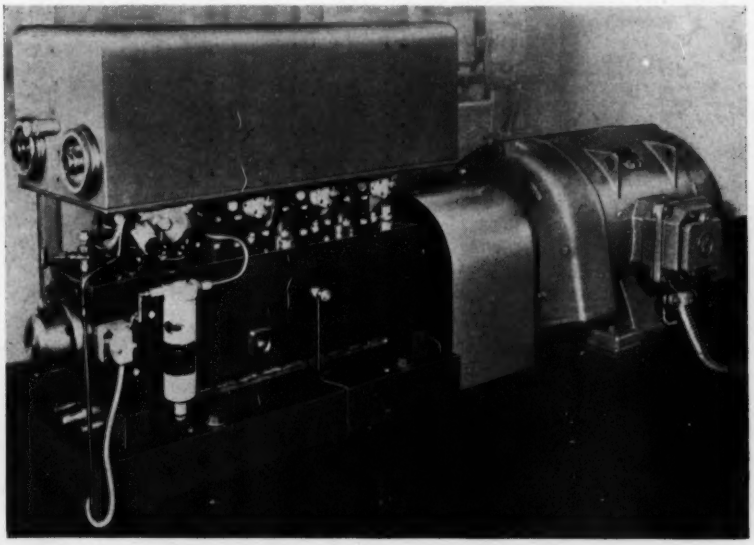
Low-temperature Refrigerator

A four-cylinder universal cooling machine, designed to meet the need in industrial processes for large-capacity, low-temperature refrigeration units, has been introduced. It is said to be ideally suitable for direct condensation in distillation processes, liquid and gas stream cooling, and for allied industrial operations calling for refrigeration in the temperature range down to −200 deg. C., and at a pressure range up to 450 p.s.i.

It is claimed to be simple and foolproof in operation, with a high reliability factor that makes it suitable for long-term operation in continuous processes.

A special auxiliary unit is available for the production of liquid air directly from the atmosphere. In addition, a fractionating column to produce liquid nitrogen is under development. These new items have no compressors and chemicals for air purification, the suction created by condensation being utilised to draw in the air supply. Moisture, carbon dioxide and other impurities are removed by a freeze-drying technique. Research & Control Instruments Ltd., Instrument House, 207 King's Cross Road, London, W.C.1.

EMD 5528 for further information



New Publications and Technical Literature

Imperial Chemical Industries Ltd.: "Terylene Industrial Buyers' Guide—Part 1, reinforced rubber and plastics products", leaflet of addresses of weavers and manufacturers. Fibres Division, Hookstone Road, Harrogate, Yorkshire.

EMD 5529

Detel Products Ltd.: Leaflet of tabulated data on the firm's protective coatings, paints, finishes, etc. Stonefield Way, South Ruislip, Middlesex.

EMD 5530

The Plessey Co. Ltd.: Well-illustrated 52-page brochure describing the range of UK-AN connectors. Wiring and Connectors Division, Cheney Manor, Swindon, Wiltshire.

EMD 5531

Metallisation Ltd.: Leaflet giving details of the firm's metal spray heat-resistant coatings. Barclays Bank Chambers, Dudley, Worcs.

EMD 5532

Tube Investments Ltd.: Well-illustrated 28-page brochure describing the wide variety of extended surface tube made by the firm's subsidiary companies. The Adelphi, London, W.C.2.

EMD 5533

The Chloride Electrical Storage Co. Ltd.: "Modern Developments in the Storage of Electrical Power", a 28-page booklet. Exchange Publicity Services Ltd., Whitfield House, 6-10 Whitfield Street, London, W.1.

EMD 5534

Alfred Imhof Ltd.: 38-page international version of the firm's catalogue of instrument racks, cases, consoles and accessories. Every item is described in ten languages. 112-116 New Oxford Street, London, W.C.1.

EMD 5535

Rockweld Ltd.: Brochure (14 pages) giving details of Circomatic welding for storage tank construction, a specification of the machine, a table of technical data, illustrations of the Circomatic in use and typical specimens of welds. Commercial Editorial Services Ltd., 3 Creed Lane, London, E.C.4.

EMD 5536

Electropower Gears Ltd.: Illustrated brochure describing the company's range of geared motors, speed reducers and speed-increase units. Kingsbury Works, Kingsbury Road, London, N.W.9.

EMD 5537

Ultrasonoscope Co. (London) Ltd.: 37-page catalogue designed not only to set out the comprehensive range of equipment available, but also to be a valuable fundamental reference book for the newcomer to the field of ultrasonic non-destructive testing. Sudbourne Road, Brixton Hill, London, S.W.2.

EMD 5538

J. & J. Dyson Ltd.: "Casting Pit Refractories and Special Fireclay Shapes", a beautifully produced comprehensive 48-page catalogue dealing with refractories of all types for steelworks use. Stannington, Sheffield.

EMD 5539

Imperial Chemical Industries Ltd.: 17-page folder of data on Tube-in-Strip, which provides tubular passageways formed integrally within a sheet or strip of non-ferrous metal. Metals Division, Millbank, London, S.W.1.

EMD 5540

Unbrako Socket Screw Co. Ltd.: Leaflets on: fasteners of titanium and other metals; high-temperature bolts; external wrenching bolts; and one-piece all-metal stiffnuts. Burnaby Road, Coventry.

EMD 5541

EMD 5419 for further information

They ought to! They ought to! People who don't protect the inside of their tanks with Ensecote are robbing themselves. Ensecote protective linings will protect practically anything you can put inside a tank, *any* size tank. They're tasteless, odourless, easy-cleaned, sterilized—and economical to apply. Ensecote protective linings add years to a tank's life.

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Agents in Belgium, France and Holland:
FOURS LECOCQ ET ATELIERS DE TRAZEGNIES REUNIS, S.A., TRAZEGNIES, BELGIUM

News of Industry

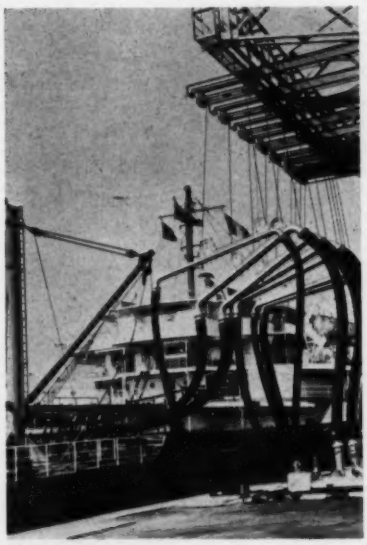
Research at the new laboratories of the **Fire Research Station** is aimed at improving methods of preventing and fighting fire. One of the latest foam compounds suitable for liquid fires is derived from slaughter-house waste, while a jet engine has been used as an inert gas generator for fire-fighting in enclosed spaces. The current programme includes a study of the mechanism of initiation and growth, suppression and extinction, and the behaviour of structures in fire. Equipment and techniques are also being investigated.

Samples of the many types of molybdenum disulphide motor oil additives on the market have been analysed at the laboratories of **Rocol Ltd.** Results show a wide disparity in both the quantities of molybdenum disulphide used, and in its quality. Some imported materials have been found to have a high silica content, which may indicate the presence of grit; amounts up to 0·5 per cent of the weight of the solid have been detected. The Ministry of Aviation limit for this impurity is 0·02 per cent. There are no fixed limits for quantity, and particle size is intimately bound up with the quantity present. A coarse powder will block filters, separate out and be non-effective; it will also remove from circulation the finer particles. When selecting molybdenum disulphide additives, products which show obvious signs of separation or admixture with other products should be rejected.

The new **Shell Centre** on the South Bank contains a benchmark to provide a datum point for Ordnance Surveys. Any datum point used for the measurement of building projects must be firmly established and unaffected by the movement of the substrata. To achieve these conditions, a steel tube was sunk into the chalk to provide what is, in effect, a long pole with the required mark on the top. To protect it from ground movements it is surrounded by a second tube, which is telescopic and free to move. To ensure spacing between the inner and outer tubes, small collars supporting rubber spacers are welded to the inner tube at 40-ft. centres. To protect the steel tubing from corrosion for an indefinite period, to keep water out of the inner tube and the annulus surrounding it, and to aid, rather than hinder, the free relative movement of the outer casing and the inner tube, the inner tube had been filled with Shell Tellus Oil 21, which is an oil containing anti-oxidation and anti-corrosion additives; and the annulus filled with Shell Alvania Grease 1, a lithium base grease which contains an inhibitor of ferrous corrosion by water.

One of the principal attractions at the recent World Trade Fair held in Turkey was the Auto-Tutor, the automatic teaching machine developed in the U.S.A. This machine, which can instruct anyone on virtually any subject from bridge or golf to complex electronic problems and abstruse mathematics, was set up on this occasion to teach first aid in Turkish. When the machine, which looks like a television set and computer combined, is in operation a page of information, including pictures or diagrams, is seen on an 8 × 11 in. screen. After studying the material, a multiple-choice question on what has been read must be answered. To answer, a code number is punched on a keyboard similar to that of an adding machine. On the screen, a new page of information either (a) verifies the answers and proceeds with the course, or (b) explains the error and directs the operator to select another answer. Moving picture sequences are used to illustrate certain points. The student's answers, and the time taken in selecting them, are automatically recorded for analysis by instructors. It is expected that the Auto-Tutor will be manufactured in England by **Burtonwood Engineering Co. Ltd.**, which was recently acquired by U.S. Industries Inc. (Great Britain) Ltd.

The Globe Pneumatic Engineering Co. Ltd. have recently co-operated with Vilain Freres, of Martigues, France, in the design of a power-operated hose-handling installation. The complete structure is entirely flameproof, since all the power units are operated by compressed air.



Once the hoses are connected to the tanker manifold the winches are declutched, and the pipes are then supported by counter-weights. The infinitely variable speed of the hoist and winch units allow accurate alignment of the hose flanges during the connection periods.

A battery of four unusual coil annealing furnaces which use an oil-fired radiant tube heating system has been ordered by James Booth Aluminium Ltd. from **AEI-Birlec Ltd.** This equipment incorporates a number of features which are expected to have a significant influence on European aluminium mill practice. Each of the four furnaces has a usable chamber 6 ft. high and 20 ft. by 14 ft., which will take a 32-ton charge of coiled aluminium strip. Heating is by batteries of temperature-controlled, oil-fired radiant heating tubes, over which the furnace atmosphere is circulated at exceptionally high speeds by eight powerful motor-driven fans. The charge is also cooled in the furnace, at a controlled rate, before being discharged. An electrically-driven charging machine loads and unloads the four furnace chambers.

A course of six lectures on Causes and Prevention of Failures is to be held at the **Institute of Technology**, Bradford, on successive Wednesday evenings at 7 p.m. commencing on January 18, 1961. The course will commence with the types of failure, fatigue being dealt with in detail for subsequent periods. Other lectures will emphasise the types of failure which predominate in various branches of engineering.

Courses in Work Study Supervisory Management and related subjects are to be held by the **Engineering and Allied Employers' West of England Association** at Engineers' House, Clifton Down, Bristol. Programmes are now available for these courses, which vary in length from two days to eight weeks.

The tenth annual Journée de l'Etain was held in Brussels on the subject of The Electrodeposition and Applications of Tin and Tin Alloy Coatings. R. M. Angles, head of the electrodeposition laboratories of the **Tin Research Institute**, presented a paper on tin-nickel and tin-zinc alloy coatings and their applications, and C. J. Thwaites, assistant chief metallurgist of the Institute, a paper on the solderability of tin and tin alloy coatings. Monsieur J. Browet, head of the laboratories of Sabena, gave a paper on tin-lead electrodeposits and their applications, and the subject of a paper by Monsieur Riesser, of the Société Minerve de France, was tin alloy electrodeposits in the electronics industry.

FILMS

A film, "Dustbins Get the Sack", demonstrates the hygiene and convenience of paper sacks made by **Reed Medway Sacks Ltd.** as disposable refuse containers. This 16-mm. sound film is available on free loan from the Sales Development Department, Reed Medway Sacks, Maidstone.

A new film release announced by **Brook Motors Ltd.** is "The Brook", a 16-mm. colour sound production with a running time of 28 minutes. It is the story of a Yorkshire river, and of some of the industries it passes on its way to the sea. It is available on free loan.

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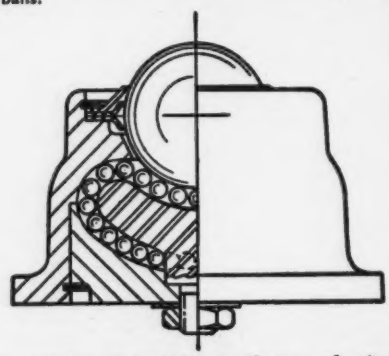

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